

# Technical principles of electronics housings

Solutions for DIN rail use

# Electronics housings

## Design, materials, and tests

Electronics housings are an elementary part of a device. They do not just determine the appearance of the device, they also protect the electronics from external influences and enable installation in superordinate units. A variety of details have to be taken into consideration during the design process, but also when selecting the housing, to ensure that these tasks can be fulfilled. These details will be discussed further throughout this brochure.



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# 1

## Electronics housings as a part of the control cabinet

Electronic devices usually consist of the electronics themselves, the enclosing housings, and the connection technology for conductors and cables. During installation in the control cabinet, a large number of interdependencies arise; these will be described in detail in the following.

### 1.1 Control cabinets, control cabinet standardization

Control cabinets accommodate the electrical and electronic components of an industrial system, a building, a machine or another production-related installation. The DIN EN 61439 standard (equivalent to IEC 61439 and VDE 0660-600) describes the requirements for all low-voltage switchgear assemblies, including the verification requirements. The standard applies to power distribution boards, all switchgear and controlgear assemblies, meter cabinets, and distribution cabinets for private and commercial buildings. Furthermore, it also extends to construction-site power distribution boards and cable distribution cabinets, as well as switchgear assemblies in special areas such as marinas.

A basic distinction is made between:

1. Power distribution boards, main distribution boards
2. Building installation distribution boards
3. Switching devices and controllers in wall cabinets
4. Meter cabinets and building distribution boards (in accordance with DIN 43880)



How the DIN rails are mounted in the control cabinet is of great importance for the design of the electronics housings. Depending on the control cabinet, the DIN rails are either free-floating on a carrier frame with clearance to the rear panel or screwed directly onto the rear panel or onto an inlaid mounting plate. In cases where the devices are too heavy for DIN rail mounting, or if there is not a suitable DIN rail mounting option on the device (see also page 7, Fig. 9), devices are also mounted directly onto a mounting plate without the use of a DIN rail.

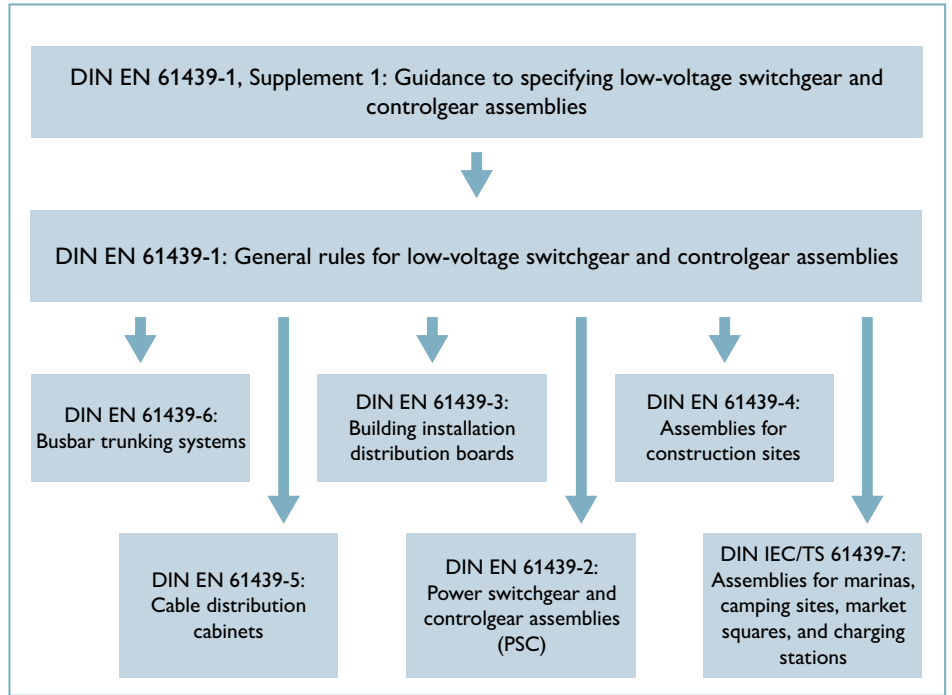


Fig. 1: DIN EN 61439 structure

## 1.2 DIN rail mounting in the control cabinet

There are three main methods of mounting the DIN rails for accommodating devices and terminal blocks, depending on the control cabinet version and make (see Figs. 2-4).

In larger industrial control cabinets, the DIN rails can be positioned

individually. This applies both to control cabinets with a mounting plate and those with a carrier frame. Holes are pre-drilled to enable easier mounting. Terminal housings and junction boxes are often designed with screw bosses for mounting DIN rails or small mounting plates. In

building installation distribution boards, the DIN rails are screwed or riveted to a frame with a clearance of 125 mm. The riveted versions can only be moved with a certain amount of effort.

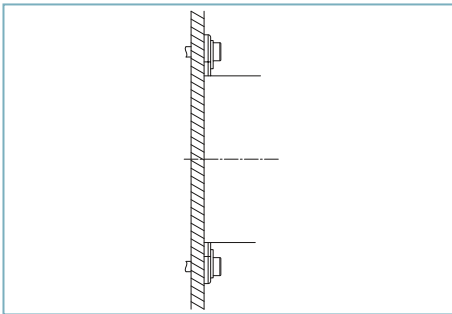


Fig. 2: Mounted onto the control cabinet rear panel via raised screw boss

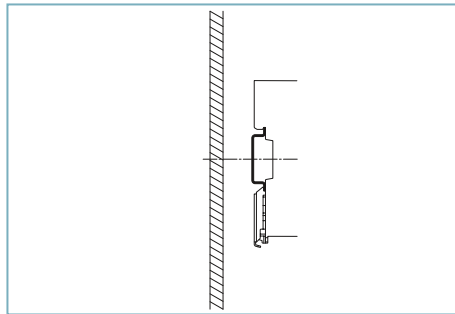


Fig. 3: Mounted on a carrier frame with clearance to the rear panel

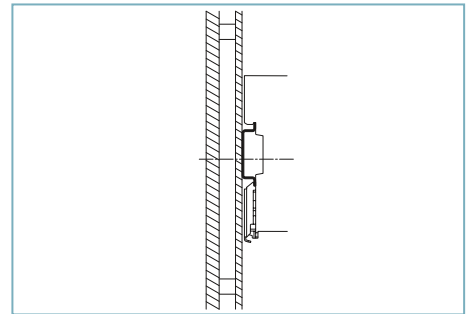


Fig. 4: Mounted directly on a mounting plate

## 1.3 Device mounting

The DIN rail mount in the base area of electronics housings consists of a fixed bearing and a movable snap-on foot. The snap-on foot is equipped with a spring mechanism such that it can be reopened once snapped into place. In metal versions, this is mainly a steel spring. In plastic versions, this mechanism is an integrated part of the plastic foot, which can be designed as a separate part or as a part of the housing itself (Fig. 5).

This combination of fixed bearing and snap-on foot enables the device to be snapped onto (A) the DIN rail and removed (B) again easily (Fig. 6).

If the height of a housing is greater than 90 mm and the DIN rail (flat rail version 7.5 mm) is mounted directly on a mounting plate, this makes snapping on and removing devices considerably more difficult (Fig. 7, left). There is insufficient space between the device and mounting plate in this case.

Using a second snap-on foot in place of the fixed bearing eliminates this problem. The height of the housing is no longer important, but in this case it must now be positioned on the DIN rail vertically (Fig. 7, center). With this method, the device is removed by releasing both snap-on feet at the same time. Some housings that utilize this method feature a park position into which the first snap-on foot can be set in order that the second can be released. This is a feature of the BC building installation housing range, for example.

As an alternative, the housing can be set to an angle of approximately 15 degrees on the fixed bearing side. In this case, a single snap-on foot is again sufficient (Fig. 7, right). This angling, and the resulting housing contour change, can have a negative effect on the board space because the printed-circuit board will also have to have this contour.

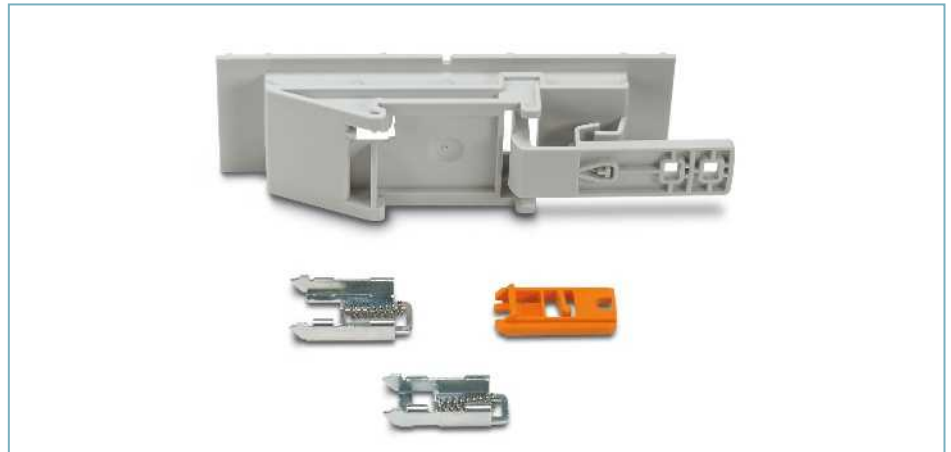


Fig. 5: Common base latch versions in metal, plastic, and integrated designs

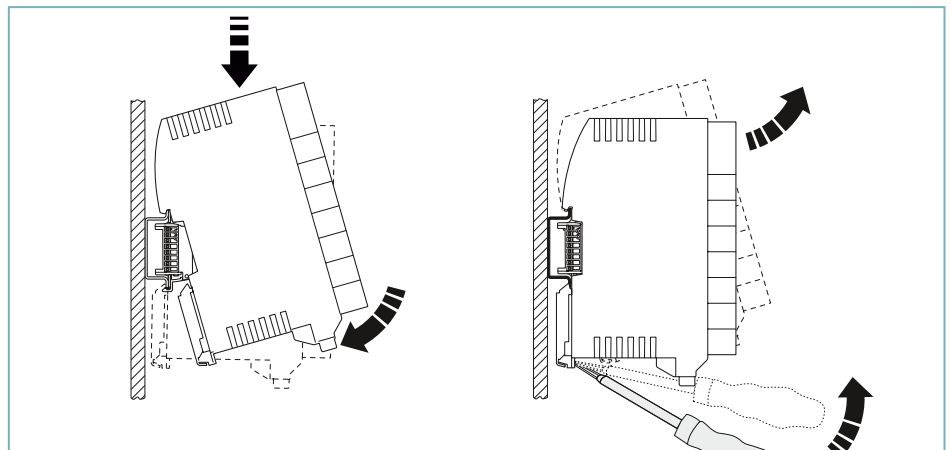


Fig. 6: Snapping on and removing housings from a standard DIN rail

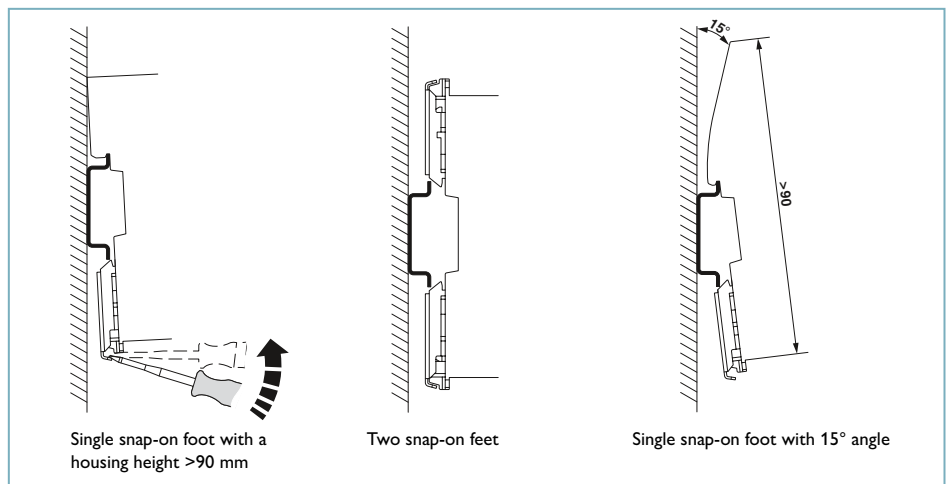


Fig. 7: Design of base latches

## 1.4 Standardized DIN rails in accordance with DIN EN 60715

The introduction of thermoplastics into electromechanical engineering opened up completely new base latch design possibilities. Whereas previously, several individual parts were required for the construction of a snap-on foot, the new material enabled the direct injection of DIN rail feet, in particular on terminal blocks. As a result, the simple top-hat rail with a C profile became the preferred choice instead of the more complex G profile. Today, the 35 / 7.5 top-hat rail described in DIN EN 60715 is the most commonly used.

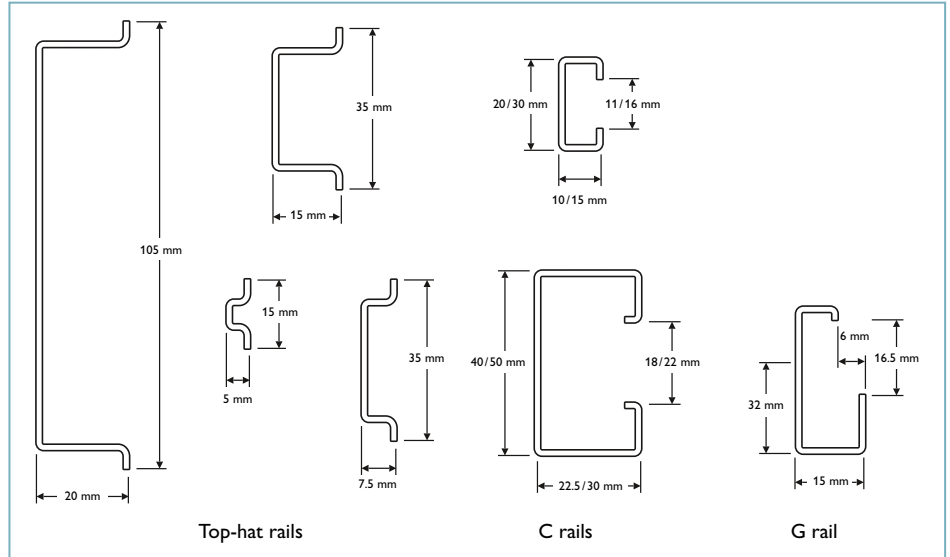


Fig. 8: Standardized DIN rails in accordance with DIN EN 60715

## 1.5 Mounting feet for heavy devices

Housings with integrated DIN rail feet are used for devices that have an overall weight of up to several hundred grams. Significantly heavier devices which are also exposed to vibrations in certain circumstances must be attached more securely. DIN rail adapters, mainly of metal, that are designed precisely for this requirement are available for this type of device.

Once the DIN rail adapter has been attached to the device, both can then be snapped onto the DIN rail. This solution is often used for power supplies and frequency converters.

These adapters are frequently also used with sheet-metal housings, where integrating snap-on feet into the design is much more difficult than with plastic housings.



Fig. 9: Heavy-duty UTA DIN rail adapters in various versions

## 1.6 Effect of the housings and connection technology on the control cabinet design

The availability of space is a key criterion in the selection of a control cabinet. Housings, connection technology, and the resulting conductor routing all have differing space requirements. The design of a housing therefore has a direct influence on the control cabinet design.

With housings with front connection technology, the cables are normally only routed in one direction from the housing into a cable duct. Such housings are therefore ideally suited for mounting directly on the control cabinet outer wall. Because the cables enter the connection block vertically, they can only be routed in an arc into the cable duct. The selected control cabinet must therefore be deep enough to enable this type of conductor routing.

Housings of the DIN 43880 design have a similar limitation. In this case, the protection cover in the standardized control cabinet limits the wiring space. In this installation situation, the conductor outlet should preferably run parallel to the control cabinet rear panel or at a 45° angle to it. A conductor outlet angled at 90° to the control cabinet rear panel can only be realized if low-profile connection terminal blocks are used (Fig. 10).

This also applies to plastic profile housings. However, in this case there are not normally any limitations imposed due to a standardized control cabinet type.

In control cabinet manufacturing, the height of a device and the conductor outlet direction are key criteria in the design of a control cabinet. In order to save costs and space, the control cabinet must be as compact as possible, but at the same time it must be able to accommodate any unplanned extensions.

The device with the greatest height on a DIN rail defines the clearance of the cable ducts, and therefore also determines the total number of possible DIN rails in a control cabinet. Where

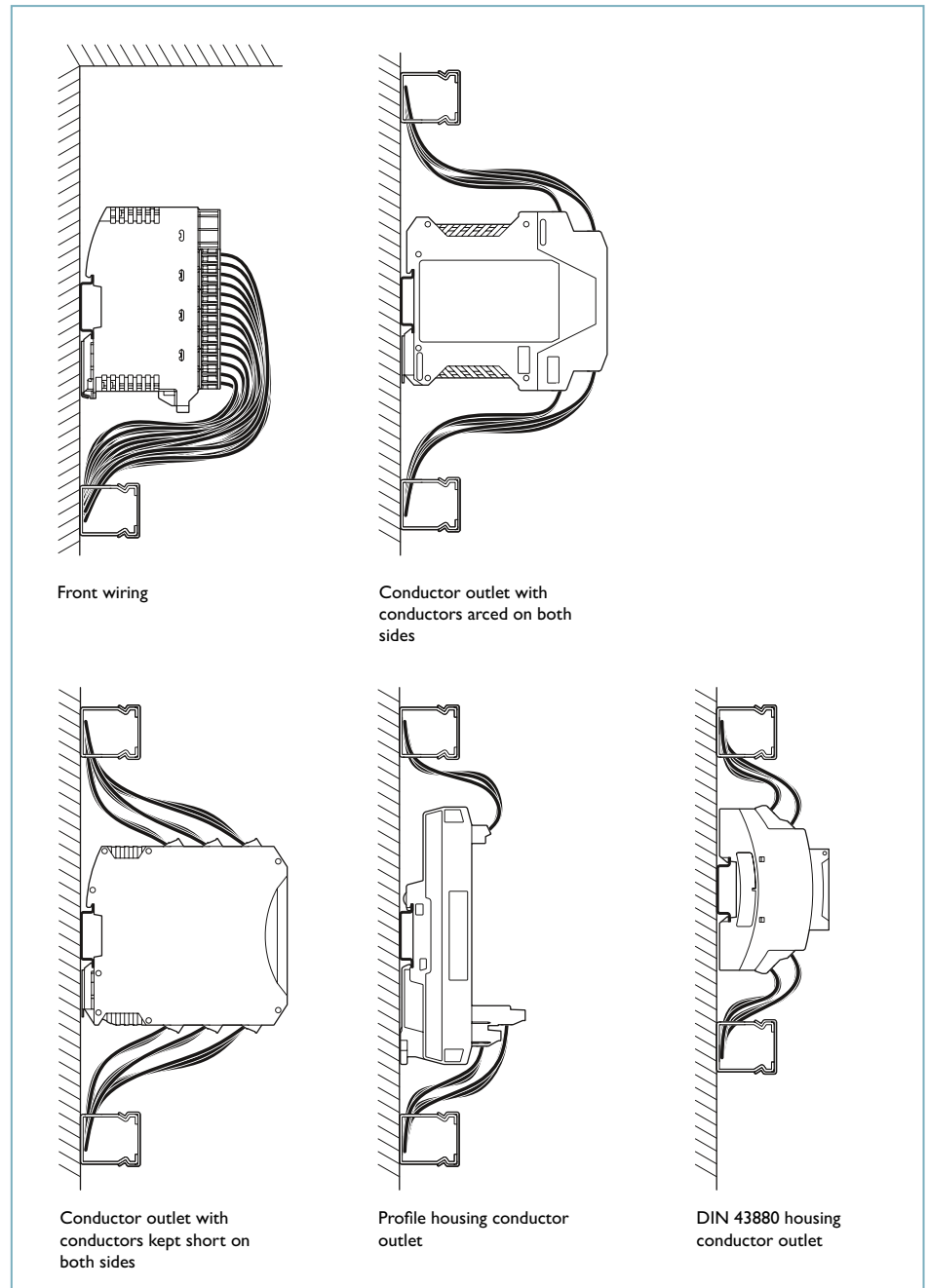


Fig. 10: Wiring

there are only minor height differences (Fig. 12), the typical basic setup is used: cable duct – DIN rail – cable duct. If there are just a few particularly tall devices necessary, the usual setup is

adapted to best utilize the space available (Fig. 12, bottom right).

In the case of front wiring with conductor outlets on one side only, a cable duct is only necessary on this



side. Such devices can therefore be installed on the upper area of the control cabinet panel to save space (Fig. 11). These front connections make wiring the device easier, because the electrician has a clear view of the contact points. Front connection provides the highest level of wiring convenience, in particular when large numbers of small conductor cross sections have to be connected. In contrast to devices with side connections, however, the conductors unfortunately cover a large part of the front of the device. Device markings and indicators can therefore only be positioned on the side of the device. This limitation is accepted in many applications, such as in remote I/O systems.

Some housing systems enable very short conductor routing if the conductor outlet of the connection technology is angled toward the cable duct (Fig. 10, bottom left). In this case, it must be noted that the conductors or plugs have to be disconnected and reconnected during service actions. Even if the device or housing design enables shorter conductors, conductors that are too short will hamper any service actions.



Fig. 11: Front connection technology with cable outlet on one side and conductor outlet on both sides in the cable ducts

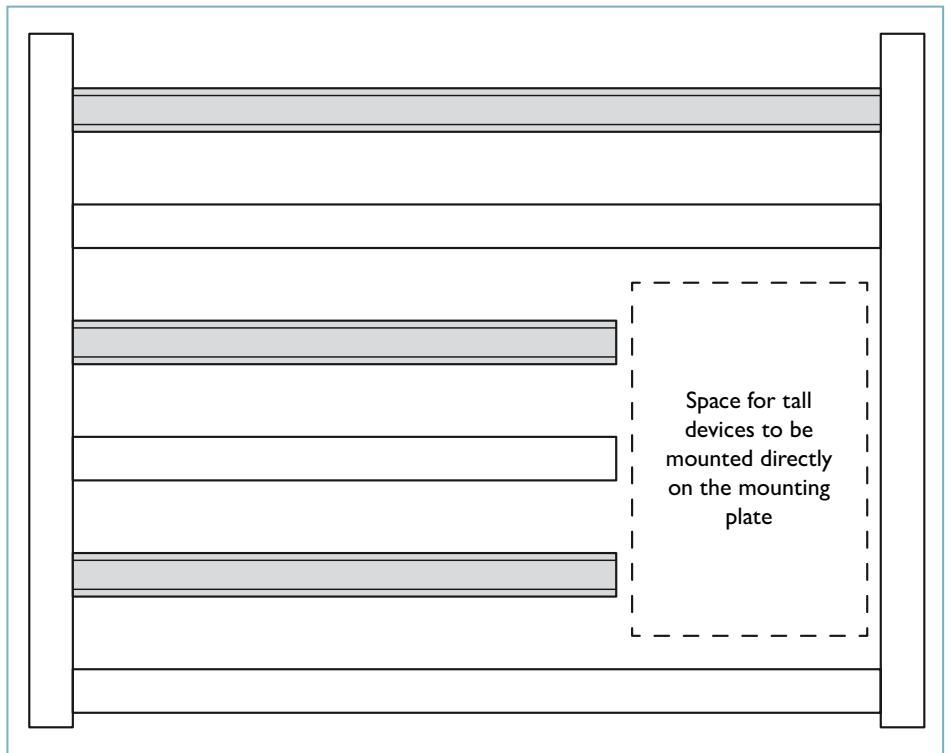


Fig. 12: Classic control cabinet segmentation: cable duct – DIN rail – cable duct

## 2 Main and small distribution boards in accordance with DIN 43880 for building installation

Distribution boards for building installation are subject to the very detailed specifications of DIN 43880. In the contemporary age of the smart home, these boards now accommodate a multitude of different devices for building control and automation applications, in addition to conventional circuit breakers and fuses. The DIN 43880 standard governs all of these devices and, therefore, their housings.

### 2.1 Small distribution boards for buildings

Small distribution boards in building installations are also accessible to non-qualified persons and so differ significantly from control cabinets on machines or in production-related systems. They therefore have to be designed such that it is not possible to touch any live parts when the control cabinet door is open. In order to prevent this, a protection cover is installed behind the control cabinet door. Only controls and status indicators protrude through a narrow slot in the space accessible to non-qualified persons.

Devices or housings that are installed in such control cabinets must therefore conform to this standard too, and comply precisely with the dimensions specified. Compliance with the dimension  $t = 44$  mm from the DIN rail upper edge to the lower edge of the protection cover is of particular importance. For housing parts that extend into the area accessible to non-qualified persons, there are recommended dimensions that can be complied with, but it is not imperative to do so.

It is important, however, that such elements remain below the maximum dimension of  $t = 70$  mm (see Fig. 13 and 14).

#### 2.1.1 Devices in accordance with DIN 43880

Devices for building installation distribution boards are often specified

with a horizontal pitch (width) of 17.5 mm. This dimension is often included in the device designation. According to the standard, the width is to be  $17.5 + 0.5 - 0$  mm. The minimum clearance between two neighboring devices is 18 mm. However, because there is always a small clearance between two devices, a device must not be wider than 17.5 mm in order that the 18 mm is maintained.

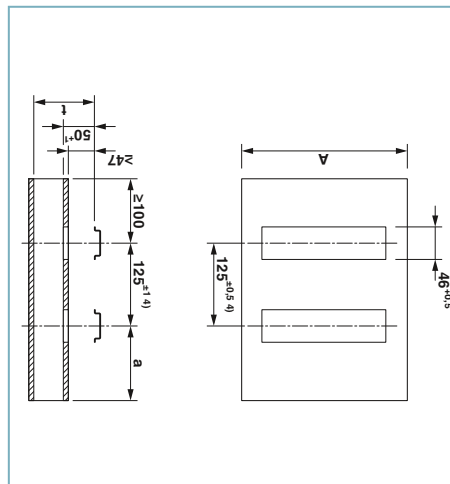


Fig. 13: Small distribution board dimensions and clearances

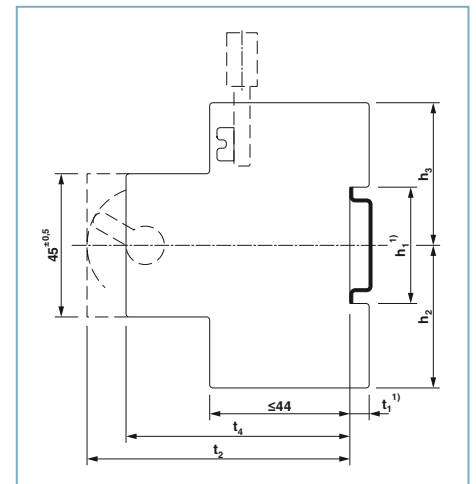


Fig. 14: Dimensions for devices for mounting on a top-hat rail

Size	1	2	3
<b>h<sub>2</sub> max.</b>	45	55	75
<b>h<sub>3</sub> max.</b>	45	55	75
<b>Preferential nominal current range I<sub>n</sub></b>	Up to 25 A	Over 25 A Up to 63 A	Over 25 A Up to 100 A

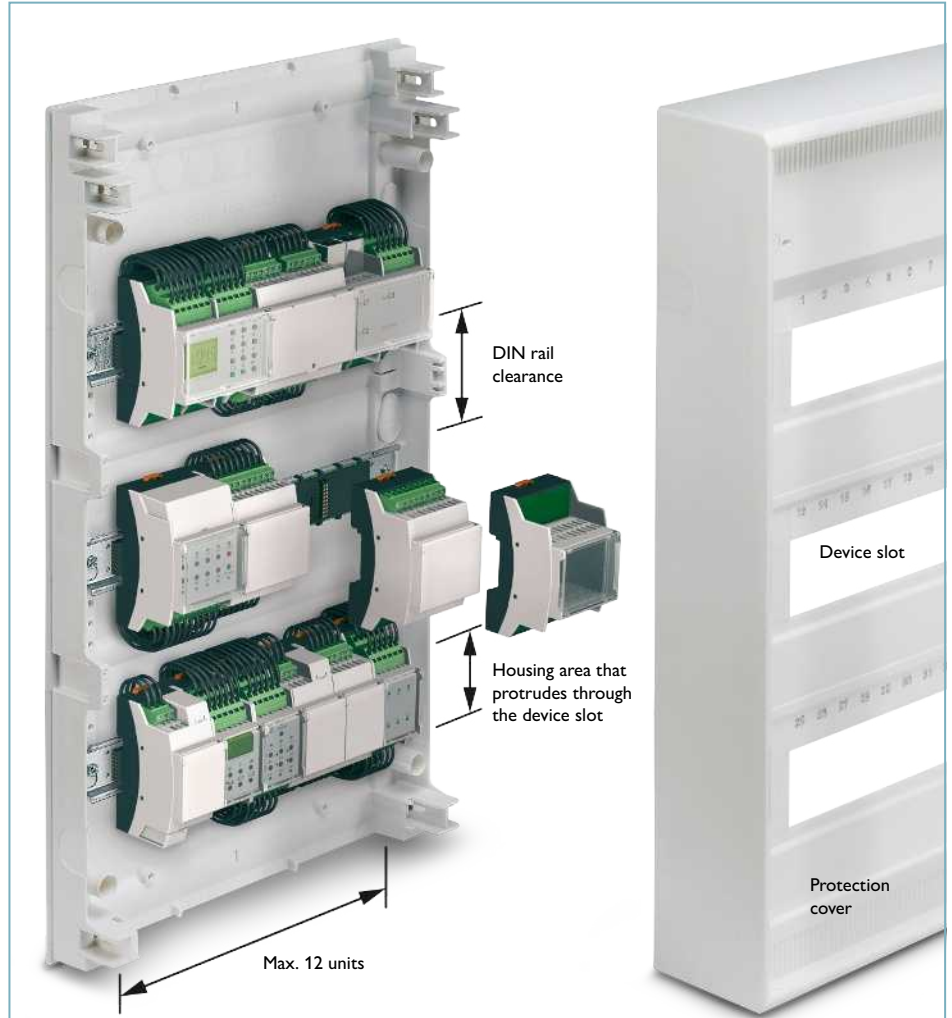
Table 1: Size dimensions for devices for mounting on a top-hat rail

<b>t<sub>2</sub> max.</b>	55	70	92.5
<b>t<sub>4</sub></b>	<b>min.</b>	52	
	<b>max.</b>	t <sub>2</sub> max.	

Table 2: Depth dimensions for devices of the sizes 1 to 4

A DIN rail length of 12 such horizontal pitches, i.e., 12 x 18 mm, is typical for small distribution boards in accordance with DIN 43880. This is based on the fact that these distribution boards were in the main originally intended for accommodating fuses and residual current devices. They were designed for single-phase alternating current and three-phase circuits. At 12 horizontal pitches per rail, 12 alternating current circuits each with one fuse, four three-phase circuits each with three fuses, or one residual current device – which takes up four horizontal pitches – plus a further eight fuses can be positioned.

Over time, simple control functions such as timers and automatic stairwell switches came into use as well. Nowadays, programmable small-scale controllers are also housed in building installation distribution boards. All of these devices, however, continue to comply with the horizontal pitches specified in DIN 43880.



<b>Horizontal pitch</b>	The horizontal pitch for devices in small distribution boards is 18 mm. The overall width of the respective devices is often 17.5 mm, 0.5 mm narrower than the pitch dimension (18 mm), in order to accommodate differences due to tolerances.
<b>DIN rail</b>	It is designed for 12 devices with a horizontal pitch (unit) of 18 mm.
<b>Device slot</b>	216 mm (12 x 18 mm) x 46 mm
<b>DIN rail clearance</b>	125 mm

Table 3: Facts on small distribution boards in accordance with DIN 43880

Fig. 15: Design of small distribution boards

# 3 Housing designs

Housings for electronic devices are split roughly into two groups: modular electronics housings, which mainly consist of two parts, and half-shell housings, which consist of several parts. There are also housings that are made of extruded profiles, but the term PCB carrier is more suitable for these. With the first two types, the design plays an important role in addition to their function, whereas the focus for the latter type is mainly on function.

## 3.1 Modular electronics housings

Modular electronics housings feature a cup design and consist of a single-piece lower housing part – the cup – and a housing cover. The connection technology is normally positioned in the cover or on the joint between the cover and the cup (Fig. 18). If appropriate guides are available, printed-circuit boards can be inserted in all three spatial directions. Thanks to the simple, two-piece design of a modular electronics housing, rapid final assembly is possible (Fig. 18).

As already stated, the positioning of the connection technology at the joint between the cover and cup in modular electronics housings is the best solution from a mechanical perspective. If a lot of terminal points are needed, the housing size quickly limits the possible number of terminal points per level.

If the connection technology is distributed across several levels and good terminal point accessibility is nevertheless to be assured, it must be inset

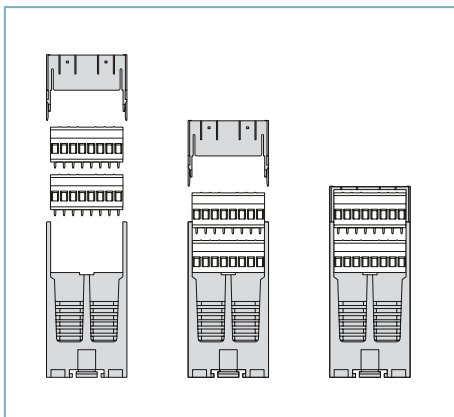


Fig. 16: Basic design of modular electronics housings

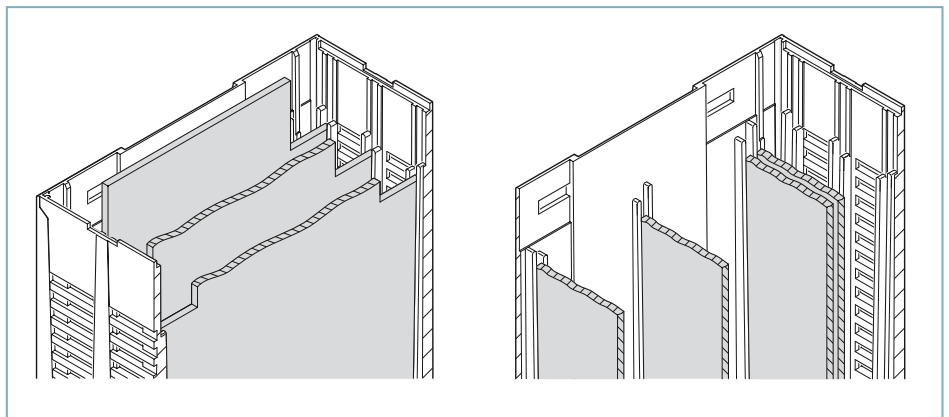


Fig. 17: Vertical PCB insertion in two spatial directions



successively from level to level (Fig. 19).

This results in a stepped design, which will have an effect on the shape of the upper housing part or the cover. A disadvantage here is the ever smaller space available on the front of the housing for indicators and markings.

The usual vertical mounting orientation of the printed-circuit boards places particular demands on the connection technology. The terminal points are typically positioned horizontally, side by side, or one on top of the next on the narrow side of the housing. However, for construction reasons, the assembly area on the printed-circuit board – on which the connection technology rests and is soldered – is offset by 90°. Orthogonal connection technology is used to resolve this issue. The desired directional change is achieved by angling the current-carrying metal parts of the terminal twice through 90°, thus harmonizing function, design, and operating convenience.

Such terminals are usually designed for just one specific housing system. In order not to stress the solder joints (see also page 20), they must adapt to the housing design and simultaneously absorb mechanical forces (which arise, for example, during connection).

The shape of the upper housing part varies depending on how many levels have been provided for the connection technology on the housing sides. Figure 20 shows typical upper housing parts from the ME housing range with two and three connection levels per side, and one version with one level on just one side.

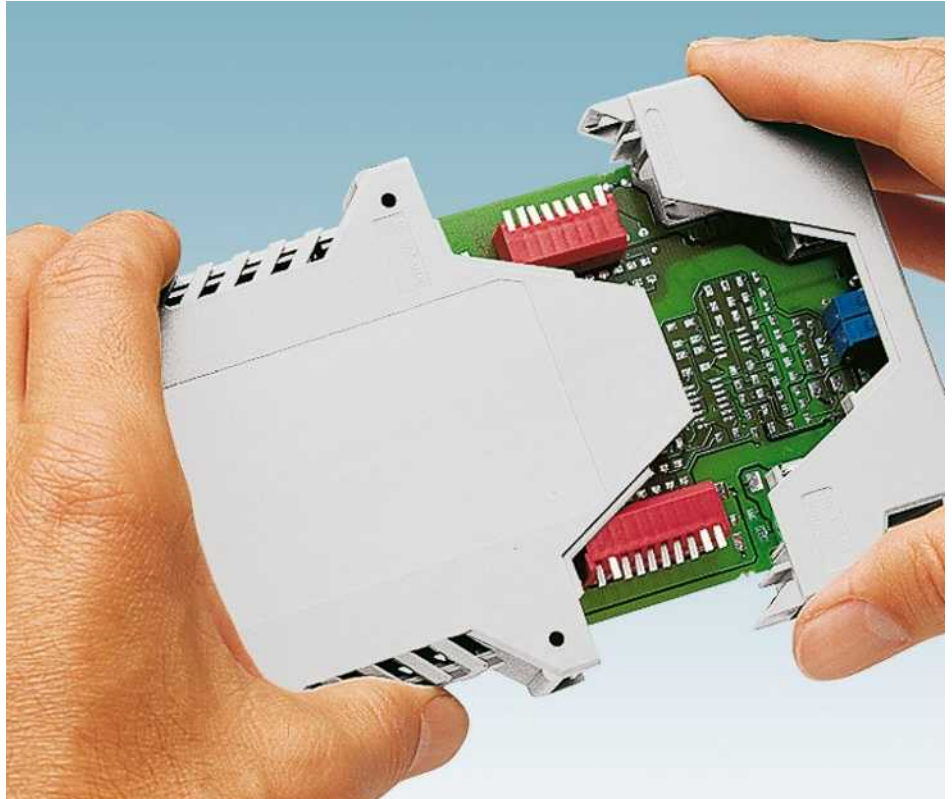


Fig. 18: Simple final assembly



Fig. 19: Inset connection technology



Fig. 20: Upper housing part designs

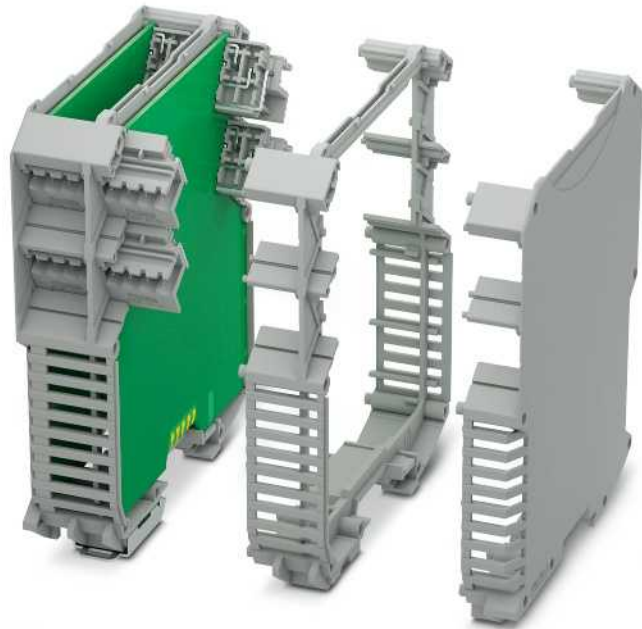
## 3.2 Half-shell housings

Half-shell housings can be easily varied in width by inserting distance pieces. This is an advantage in particular when unusual housing widths of more than 50 mm wide need to be produced cost-efficiently.

With this housing type, the printed-circuit board is inserted into the side of one of the two housing half-shells during final assembly. The second half-shell closes the housing (Fig. 22). In theory, this design enables the connection technology to be positioned on any exterior side of the housing. A larger clearance between two connection blocks can also be closed through the use of a half-shell design, even with direct vertically stacked blocks. This eliminates the need to inset the connection technology levels, as is the case with modular electronics housings.

Half-shell housings therefore enable several connection technology levels, without having an adverse effect on the front area, as is the case with modular electronics housings. Angling the connection technology increases operating convenience; in this case, however, orthogonal connection technology must also be used, due to the vertical printed-circuit boards.

Final assembly is much more complex than with modular electronics housings.



The half-shells are latched at many points to close all contours and stabilize the housing. The snap-on foot, which in the case of modular electronics housings is integrated into the housing or pre-assembled, often has to be retrofitted here in the final device assembly.

Because the connection technology does not have to be inset in the case of a half-shell housing, a larger printed-circuit board assembly area is available in comparison with modular electronics housings with the same dimensions (length x width x height). This increase

in assembly area versus the rapid final assembly of the modular electronics housing are the most important factors in deciding between the two housing designs.

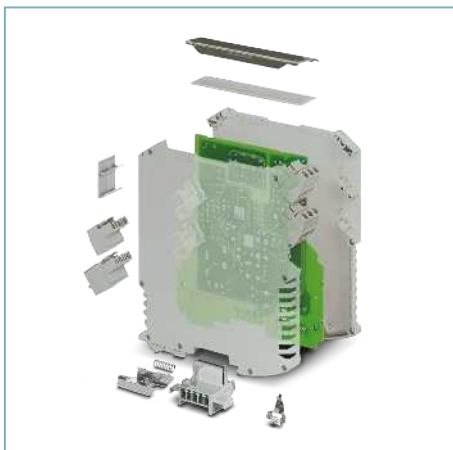


Fig. 21: Half-shell housing design

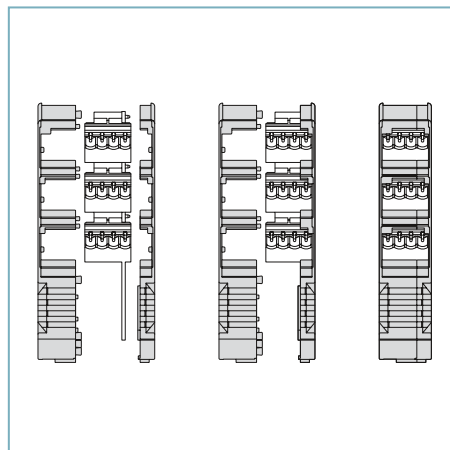


Fig. 22: Assembly sequence

### 3.3 Profile housings

The term electronics housing is not quite right for the profile design. A more suitable term here is PCB carrier. They are manufactured from a continuous extruded profile, which is shortened to a transportable length of 2 m after production. The sections are then cut to the desired length with millimeter precision.

The profiles usually have several grooves for accommodating printed-circuit boards. A blocking area is provided on the printed-circuit board for this groove when positioning the connection technology and the electronics. With some designs, the uppermost PCB receptacle can optionally enable the connection technology to be assembled on the edge (Fig. 24).

Side elements, which are available in a variety of designs, are used to close off the profile ends. These are either screwed onto the profile or, in the case of the rapid assembly versions, simply snapped into place (Fig. 23). Because the profiles do not have rear grooves due to how they are processed, an additional cut

which serves as a rear groove for the side elements is made when they are cut to length.

The foot for mounting on the DIN rail is integrated into the side elements. As is the case with most housings, this comprises a fixed bearing and a flexible plastic part. The housing is completed with a plastic cover, which is cut to the respective length of the profiles.

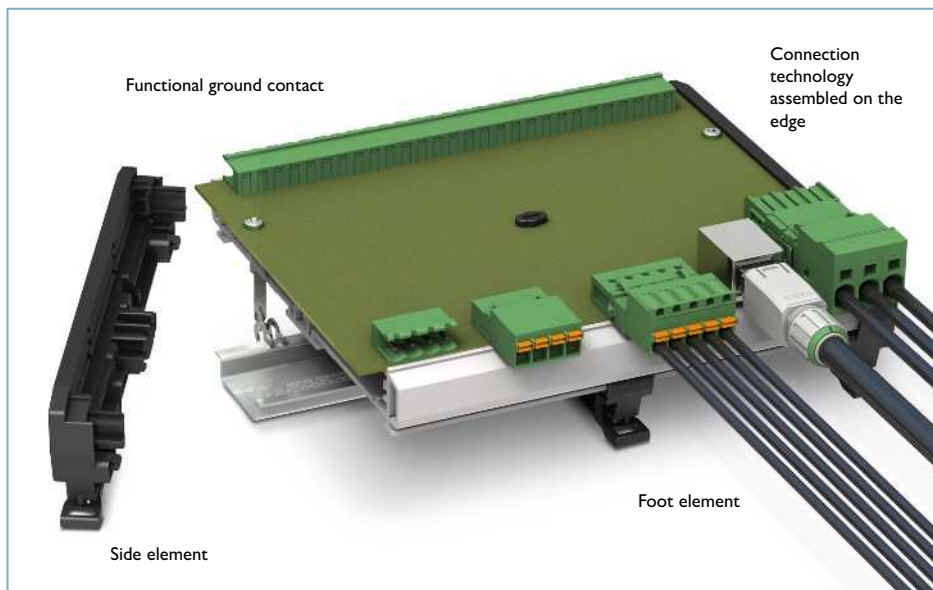
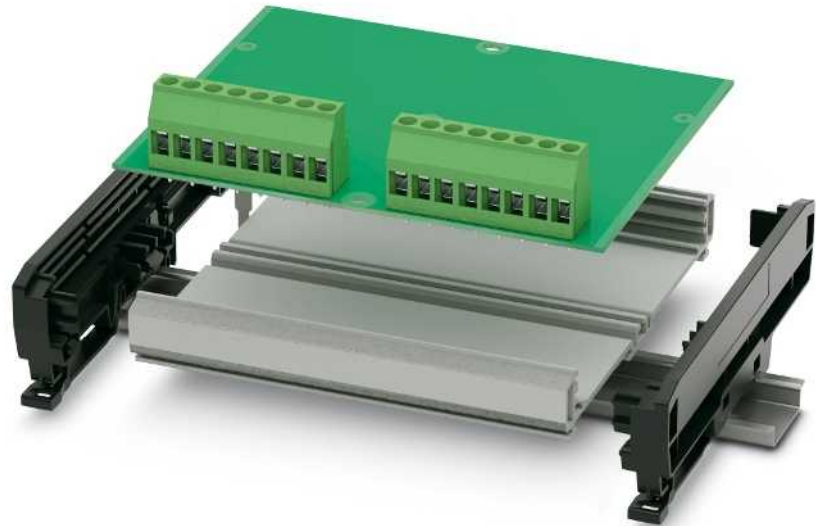


Fig. 23: Screw-free side elements



Fig. 24: Edge assembly on a profile housing

# 4 Mounting orientation of the printed-circuit boards and connection technology

In electronics housings, printed-circuit boards are either aligned horizontally or vertically to the DIN rail. This affects the device in many ways, because the orientation of the printed-circuit board limits which functional connection technology can be selected and determines the conductor outlet direction. It is therefore always an advantage if a housing enables different mounting orientations.

## 4.1 The mounting orientation

### 4.1.1 Horizontal PCB arrangement

Flat modular electronics housings and profile housings have a horizontal PCB arrangement. This results in relatively large housing fronts with plenty of space for indicator and control elements. Another advantage is that in addition to the system components, almost the entire range of commercially available

connection technology – such as D-SUB, RJ45, and USB – can be used easily.

However, the horizontal orientation does not necessarily dictate a horizontal conductor routing. Through the proactive selection of the connection technology, the conductor outlet direction can be varied for a given PCB orientation. It can be angled just as easily to 45° or 90° below the printed-circuit board, if this will be beneficial when using the device.

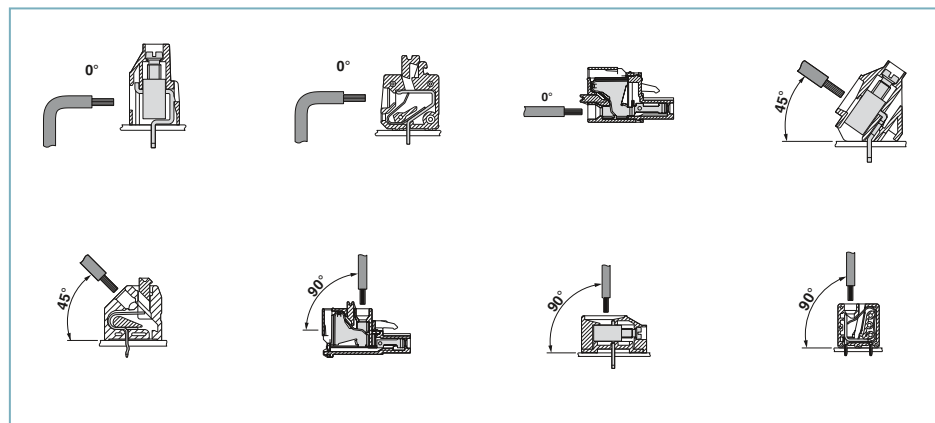
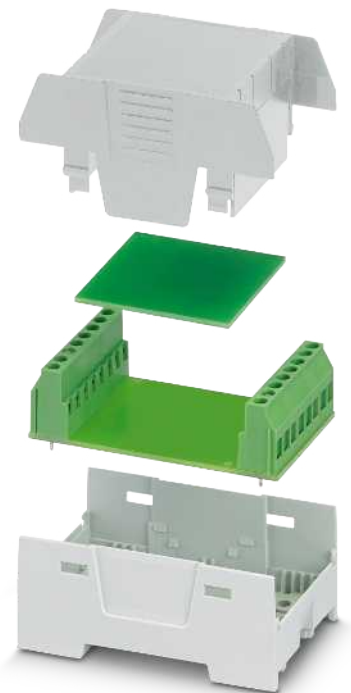


Fig. 25: Conductor outlet direction of various plugs and headers





Therefore, if a horizontal printed-circuit board is selected, a sufficient level of freedom remains in terms of the conductor outlet direction (Fig. 25). With profile housings, the production method (extrusion) almost exclusively dictates the horizontal mounting orientation of the printed-circuit boards.

A large number of housings also enable the arrangement of printed-circuit boards above one another in two or more levels.

Coding the levels is a good method of making the final assembly of such devices easier. Thus, one printed-circuit board fits exactly into one specific position in the housing, and is mounted quickly and securely. In the example shown in Fig. 28, each PCB level is assigned at least two square latch-in positions in the housing side wall. Because these positions are offset from level to level, there is only one suitable PCB/latch-in point combination per level.

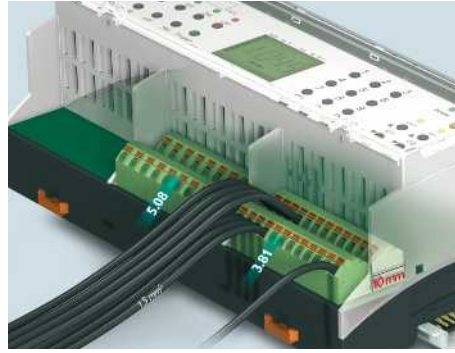


Fig. 27: BC housing with 45° conductor outlet

### 4.1.2 Vertical PCB arrangement

The vertical PCB arrangement is used in tall modular electronics housings and half-shell housings. The printed-circuit boards are guided into insertion grooves, which are often provided for two spatial directions. However, only a connection technology that has been adapted for this design can deliver the necessary functionality.

In order to ensure that the operating direction and conductor outlet are as convenient as possible for the user – as is the case with a horizontal orientation – orthogonal connection terminal blocks are needed (Fig. 26).

The actuator (in this case a connection screw) and the solder connection are in a line with the vertical printed-circuit board. The solder/connector metals are



Fig. 26: Orthogonal MSTBO connection terminal block

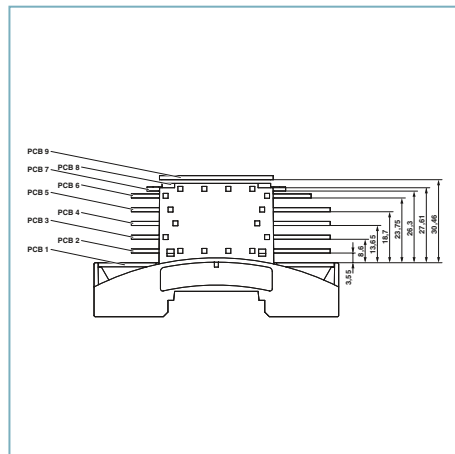


Fig. 28: Stacked PCBs in the BC housing

turned through 90° twice (orthogonal connection technology) for the conductor outlet. This enables the terminal to be connected and operated ergonomically. The integration of third-party components is possible with the vertical PCB orientation, but is not as elegant, because such components are usually only turned through 90° once.

## 4.2 Connection technology

There are two basic designs for the PCB connection technology: fixed connection directly on the printed-circuit board, and pluggable connection.

### 4.2.1 Fixed connection

The fixed connection is of one piece and connects the conductor directly to the printed-circuit board. In comparison with a pluggable solution, the fixed connection is more economical in terms of material costs. In the event of service actions or module replacements, the conductor has to be detached then reconnected later. If the conductors are not clearly marked or labeled, this can lead to incorrect connections, and therefore to device damage. Terminals for a fixed connection are available in a huge range of designs and colors. They come with screw or spring technology, which ideally can be used interchangeably in the same layout. The wave soldering process is typically used for one-piece terminals. The high metal content is problematic for processing using the reflow soldering process, because the one-piece design includes screws or springs, terminal sleeves, and solder pins. Firstly, the high metal content at the soldering point draws a great deal of heat, and secondly it makes balancing on the printed-circuit board more difficult.

The versions of this connection technology are shown in Table 5 on page 20.

### 4.2.2 Pluggable connection

Pluggable connections always consist of at least two pieces. The conductors are connected to a plug and are then connected to the printed-circuit board via a second component, the header. Pluggable connections enable the rapid

replacement of devices. With these connections, the danger of mismatching connections when reconnecting is already significantly lower. Through the use of coding and various colors, this danger can be practically eliminated.

Thanks to the two-piece design, the header to be soldered has only a low metal content. It is therefore very light and can be balanced easily for automatic assembly. Pluggable solutions for both the wave and reflow soldering process are available with the same layout (pinning).

The terminals for reflow soldering are made of a high-temperature plastic in order that they can withstand the temperatures in the soldering autoclave. They are available in blister packs off the roll for automatic assembly processes (Fig. 30).

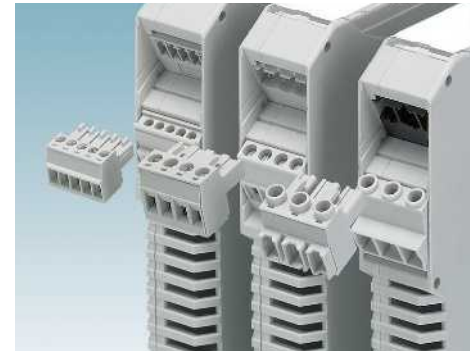


Fig. 29: Comparison – fixed vs. pluggable

Property	Fixed connection technology	Pluggable connection technology
Number of components	1	Min. 2
Contact resistance	+	-
Space required on the printed-circuit board	+	-
Flexibility in production	-	++
Convenience in the event of service actions	-	++
Reflow-capable	No	Yes
Total costs due to number of parts	+	-
Control cabinet preassembly possible	No	Yes
Color versions available for function recognition	Yes	Yes
Coding	Not necessary	Yes

Table 4: Comparison of fixed and pluggable connections

### 4.3 Dependence of the production process on the connection technology

The choice of connection technology and the subsequent production process are closely interlinked.

The soldering process is defined in the early stages of development. If an SMD assembly with a reflow soldering process is decided upon, the use of single-piece, fixed connection technology is practically ruled out, because there are very few suitable products available on the market.

If the future device is to be made available with fixed connection technology with both screw and spring connection versions, one production line is necessary for each version. The final product is therefore defined right at the start of device production – during PCB assembly. By the same token, a decision to use fixed connection technology is at the same time a decision to use the wave

soldering production process.

An advantage of pluggable connection technology is that there are identical products available for both the reflow and wave soldering processes. Since the conductor connection is located in the plug and only added to the device at the very end, the decision as to whether the product will later have a Push-in, screw or spring connection remains open until the end of the production chain. With pluggable connection technology, therefore, a decision on the connection method only needs to be made at the end of the production chain. This represents a significant cost benefit, because all versions are produced on a single line up until this point.



Fig. 30: Headers in blister packs off the roll

Decision		Effect	
Development		Production	Delivery
Connection technology	Soldering process	Start	Finished device
Fixed	Wave	Production line Wave 1 Production line Wave 2 Production line Wave 3	Screw Spring Push-in
	Reflow	No technical solution	
Pluggable	Wave		Screw Spring Push-in
	Reflow		Screw Spring Push-in

Fig. 31: Schematic illustration of the dependency between connection technology and production process


























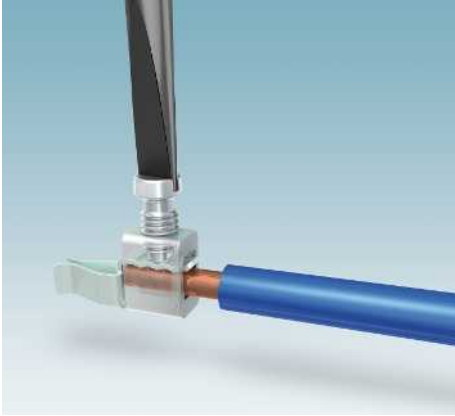
	Pitch	Number of positions	Wave soldering		Reflow soldering	
			Screw	Spring/Push-in	Screw	Spring/Push-in
Fixed connection	3.5	3 – 5	 MKDSO 1,5		Technical solution not available	
	5.0	2 – 4	 MKDSO 2,5	 FKDSO 2,5		
	7.5	2/3	 MKDSO 2,5 HV	 FKDSO 2,5 HV		
Pluggable connection	3.5	3 – 5	 MCO	 MCO	 MCO THR	 MCO THR
			 MC	 FMC	 MC	 FMC
	5.0	2 – 4	 MSTBO	 MSTBO	 MSTBO THR	 MSTBO THR
			 MSTBT	 PSPT	 MSTBT	 PSPT
	7.25	2/3	 GMSTBO HV		 GMSTBO HV THR	
			 GMSTBT HV		 GMSTBT HV	

Table 5: Overview of the connection technology for the Phoenix Contact ME and ME MAX housing ranges



### 4.3.1 Connection technologies in comparison



#### Screw connection

- Known throughout the world and intuitive to operate
- High conductor compression forces
- Suitable for all conductor types
- Can be used with or without ferrules



#### Spring-cage connection

- Connection chamber has to be opened before the conductor can be connected
- Suitable for all conductor types
- Can be used with or without ferrules



#### Push-in connection

- Rigid conductors and conductors with ferrule are inserted and connected directly without opening the connection chamber
- With flexible, fine-stranded conductors, the connection chamber is opened first
- Least time needed per terminal point

### BGV A 2 accident prevention regulations

The accident prevention regulations BGV A 2 issued by the German employer's liability insurance association for precision mechanics and electrical engineering are targeted at operators of electrical systems, with the aim of accident prevention. They relate to performing work and operations near to and occasionally handling (live) parts that pose a danger if contacted in low-voltage systems up to 1000 V AC or 1500 V DC.

The key determination is that a touch-proof area in the form of a level envelope with a radius of 30 mm is to be established surrounding live parts (see DIN EN 50274).

This is tested in accordance with IEC 60529 or DIN VDE 0470-1 with a standardized test finger.



Fig. 32: Header in accordance with BGV A 2



Fig. 33: Header that is not touch-proof

## 5 Accessories for special functions

If adapted functional accessories are added to an electronics housing, the housing becomes a housing system. Among others, these functional accessories include the previously discussed connection technology, status indicator elements, and device-to-device connectors (buses). They also include potential and shield connection elements.

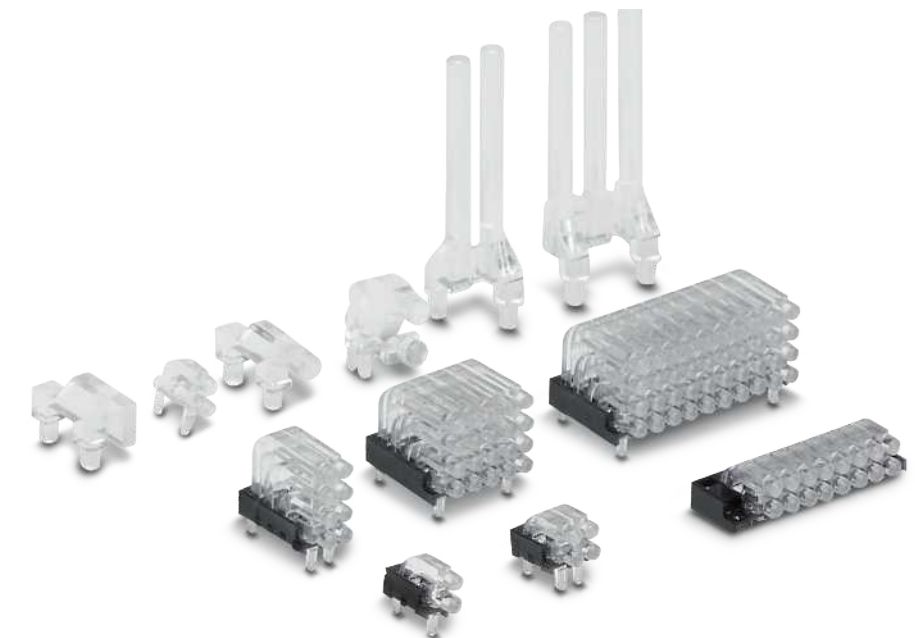
### 5.1 LED status indicators

The implications of the printed-circuit board mounting orientation are the same for indicator and control elements as they are for the connection technology.

With horizontal printed-circuit boards, it is also possible to install light guides with a relatively simple construction. With vertical printed-circuit boards, the light has to be redirected similarly to the conductor path in orthogonal connection technology. In contrast to the connection technology, however, the light-emitting surface is not the housing side panel, but the housing front. With light guides, a single 90° turn is therefore sufficient.

Light guides are generally positioned such that they pass through the housing panel and terminate flush with the front surface. If light guides have a rounded light-emitting surface, this should protrude from the front by the radius of the rounding. Firstly, this avoids dirt-collecting edges. Secondly, the angle from which the indicated status can be read off conveniently is increased.

Depending on the design, LEDs can also be routed directly through the housing front. Dirt-collecting edges are



also to be avoided here. Added to this is the danger of ESD pulses that can penetrate through the LED opening into the housing interior. A partially transparent film label can be used as a countermeasure to this.

Light guides are available in a huge range of versions and designs. They must ensure the low-loss transmission of light and be highly homogeneous in design. If this is not the case, two light guides routed side by side may produce different lighting impressions. This can lead to confusion when the user is determining the device status.

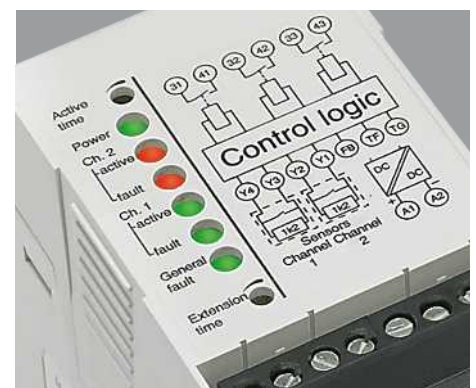


Fig. 34: Housing front with LED indicators

### 5.1.1 Light guides with a high packing density

Especially with housings with front connection technology and a high connection density, there is little space available for status indicators (Fig. 35). Light guides that enable a high packing density are ideal for such cases. This high packing density enables a light guide block pitch of 2.54 mm and a diameter of 2 mm per light guide. These are normally designed for CHIPLEDs of the type 0603 or smaller (Fig. 36). An aperture integrated into the light guides prevents the light being transmitted from one light guide to the next, thus enabling the display of different colors in one block. Press-in pins ensure secure positioning on the printed-circuit board.

The light guide blocks can be adapted to the application. Variations can be created through different numbers of rows and columns, as well as partial assembly and combinations. When using light guide blocks, either the light guides or the housing should have beveled edges as insertion aids to simplify final assembly.

Light guides are often made of transparent polycarbonate. A material of flammability rating of UL V0 (see also page 34) is ideal, as this is frequently required for electronics housings. With an optimized lighting design in terms of material, shape, and diameter, a high-quality visualization system can then be achieved.



Fig. 35: Light guides in the ME-IO housing for a compact indicator area



Fig. 36: 5x4-row light guide block

### 5.1.2 Flexible light guides



Fig. 37: Flexible light guide

When positioning light guides, mechanical or electronic limits are encountered in some applications. The typical designs require proximity to the indicator area, which is not always easy to achieve if the electronics packing density is high or if the housing geometries are complicated. Flexible light guides (Fig. 37) enable LEDs to be positioned practically anywhere on the printed-circuit board. The light is guided via two end caps and a flexible part, including in loops if necessary. The light guides can be cut to the optimum length via a careful incision using a very sharp knife, and are therefore ideal for these applications. For housings with a high IP protection class, the light exit cap can be affixed with adhesive to the front of the housing to form a water and dust-proof bond, thus enabling an easy-to-realize status indicator.

## 5.2 Bus systems

### 5.2.1 DIN rail buses and device buses

Electronic control and regulation systems are constructed by adding various function modules, with the advantage that individual components can be easily added or removed. It is therefore simple to convert or extend a system. This requires that the function modules are connected together via a bus system. Two types of bus system have become established: the DIN rail bus, which runs below the housing in the DIN rail, and the device bus, which is located inside the housing.

The DIN rail bus can be mounted independently of the housings and enables individual housings to be removed from an assembly (Fig. 38). The bus communication is not automatically

interrupted when one bus module is removed, meaning that the rest of the system remains in operation.

With a device bus, which runs inside a housing, it is not possible to remove individual modules from the assembly easily, because the neighboring modules must first be moved to one side (Fig. 39). This interrupts the bus connection. Only then can the selected module be removed from the rail. Interrupting communication is not permitted in a huge number of applications, meaning that the use of device buses is ruled out.

With device bus systems, the connection between the bus and device electronics (printed-circuit board) is established during module production. The printed-circuit board is plugged vertically into the bus contact, meaning that the contact between the

printed-circuit board and bus contact can be simple in design.

The DIN rail bus system is completely different. In this case, due to the housing construction, a module is not placed vertically onto the DIN rail, but is pivoted into place on the rail via the fixed bearing and snap-on foot (Fig. 40). The contacts thus move along a circular path, which must be reflected in the geometry of the contact pads on the printed-circuit board. An ideal design would ensure that once a contact has been made, it does not break off due to the movement and that the movement does not lead to a short circuit or a violation of the minimum clearance and creepage distances.

A good solution is to equip the outer edge of the printed-circuit board in the area of the bus contacts with a beveled edge. This acts as an aid when opening

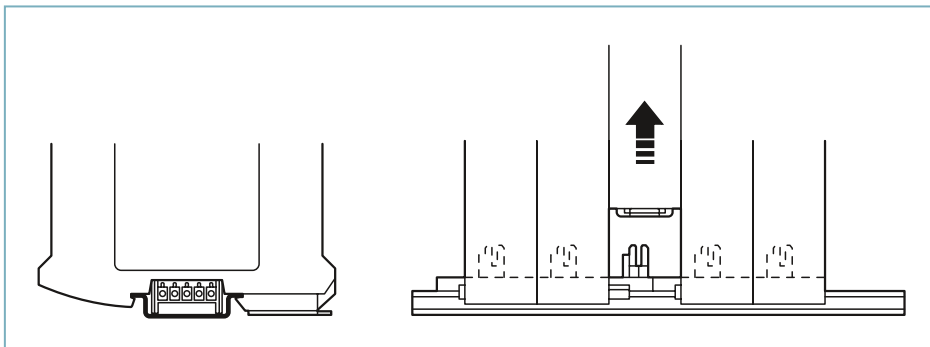


Fig. 38: Basic design of a DIN rail bus



Fig. 40: Pivoting a device onto the DIN rail bus

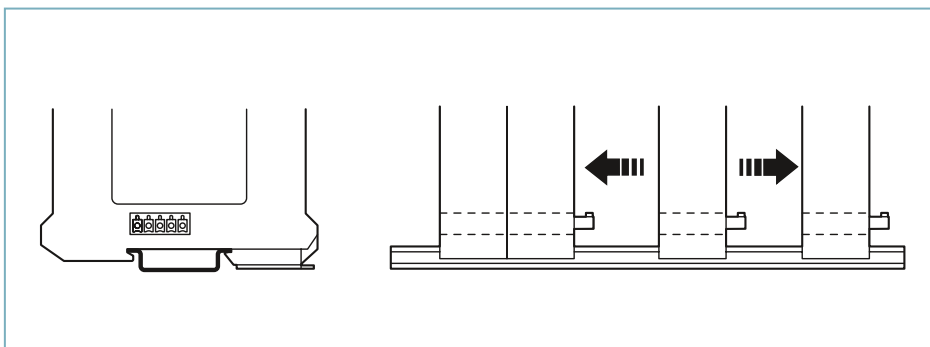


Fig. 39: Basic design of a device bus system

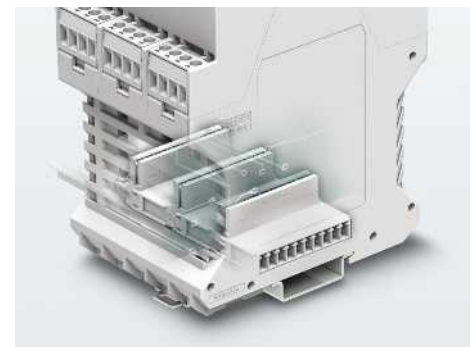


Fig. 41: Cross section of a housing with device bus

the bus contacts and provides mechanical relief during the pivoting action.

Because the DIN rail bus follows a specified pitch, and because a vertical outlet to a device or a device board is not always necessary, appropriate bridging adapters are available for this bus type (Fig. 42).

DIN rail buses are available in 5- and 8-position versions. The buses are rated for 6 ... 8 A at a voltage of up to 100 V.

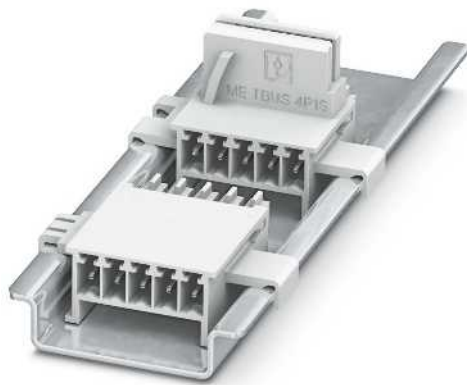


Fig. 42: Bus adapter for bridging

The DIN rail buses feature exceptionally good signal transmission characteristics, even at high speeds. They are therefore ideal for creating a local communication bus.

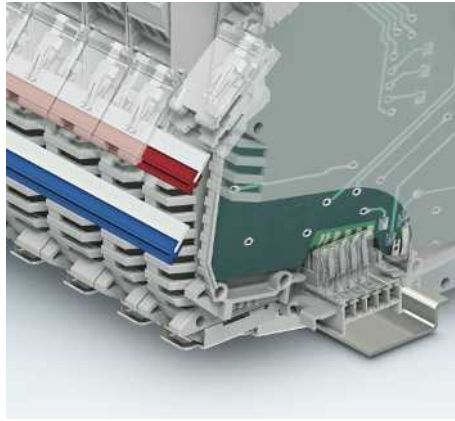


Fig. 43: Power bus

### 5.2.2 Power buses

Device and DIN rail bus systems are suitable for signal transmission even at high frequencies, and for low-power transmission. A current carrying capacity of 5 ... 10 A is typical for such bus systems. If higher powers are to be distributed, additional rail distributors have to be used, such as the power bus system for the ME MAX housing range shown in Fig. 43. Up to 30 devices can be supplied via busbars that have a current capacity of 40 A and special connection elements. Because these busbars can be installed in parallel to the DIN rail bus, the contacts are designed such that the devices can also be snapped into place and pivoted.

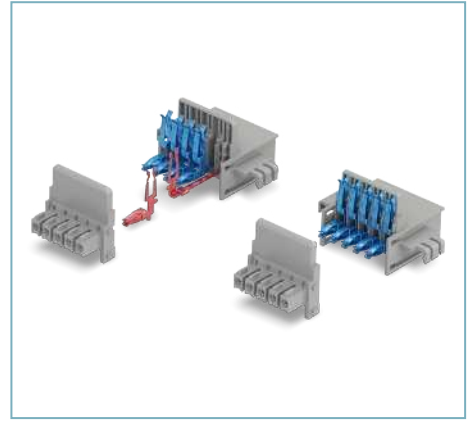


Fig. 44: Parallel and serial contacts

### 5.2.3 Parallel and serial contacts

As with the device bus, the DIN rail bus can be fitted with parallel and with serial contacts (Fig. 44). Parallel means that the feed-in, branching, and forwarding share the same potential.

Serial contacts are discontinuous contacts. The connection between feed-in and forwarding is established via the device printed-circuit board. The different contact types can be combined in any way and any number on one block. However, due to the mechanical load, the position and number of serial contacts may be restricted.



### 5.2.4 High-position buses

Wherever buses with a high number of positions are required, DIN rail buses quickly reach their physical limits. With high numbers of positions, the contacts are so delicate and the mechanical pivoting forces are so high, that deformations are to be expected.

It is easier to plug the housing onto the bus perpendicularly. In this case, pin and socket strips can be used on a printed-circuit board as the basis for the bus configuration (Fig. 45/46). The use of a printed-circuit board also enables the integration of simple SMD components into the bus, such as stabilization capacitors for improving the EMC properties.

A disadvantage is that such a system often cannot work with the classic snap-on foot/fixed bearing principle; instead, a second base latch is necessary, which enables vertical plugging and unplugging, and therefore ensures that the sensitive contacts on the male side of the bus are not damaged.

Because users will intuitively attempt to pivot a module into place as is usual, this deviation from the standard must be clearly documented.

Buses that provide even more space for electronics are those that are designed for the large NS 105/20 DIN rail (Fig. 47/48). Here, the power supply, coding, configuration elements, and electronic repeaters can be integrated in addition to the signal lines.

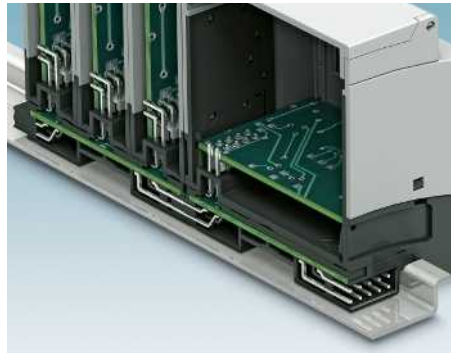


Fig. 45: Cross section of a DIN rail bus with printed-circuit boards attached

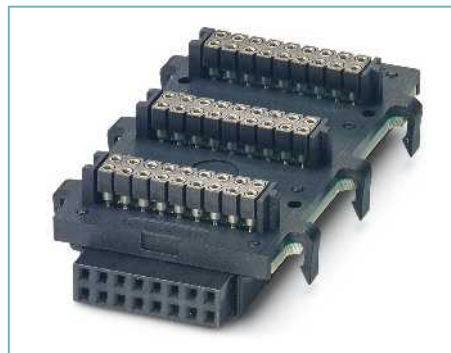


Fig. 46: PCB-based high-position bus



Fig. 47: High-position bus in the NS 105/20 rail



Fig. 48: Individual parts of high-position bus

### 5.3 Function accessories

Housings, connection technology, indicators, and bus systems form the basic framework for a housing system. Additional accessories enable these to be used in a much larger range of applications and for individual tasks, such as the electrical connection of a device to a grounded control cabinet.

If, for example, protective grounding (protective earth, PE) is necessary, the connection must be established to a fixed, non-pluggable connection terminal block. If the connection technology has been designed to be fully pluggable, the PE contact must be designed to be leading during plugging and lagging during unplugging. Furthermore, a PE contact is subject to special normative requirements (e.g., cross sections, impulse durability).

If just one equipotential bonding line for arresting static discharge is to be established, or if functional grounding (GND) is necessary, for example, as a common reference point for a data interface, then a functional ground contact directly in the base area of the housing with a connection to the DIN rail is normally sufficient (Fig. 49/50).

Such contacts, however, never satisfy the electrical requirements that are placed on PE contacts.

If the cable shielding of a signal line is to be connected to the electronics, shield connection clamps are used (Fig. 51). Here, one terminal point of the connection technology is occupied with the terminal lug of the shield connection clamp, and the exposed cable shielding is inserted into the clamp and secured with a screw, as is the case with a strain relief system.

Note: When using shield connection clamps and functional ground contacts at the same time, it must be ensured that this configuration does not give rise to a grounding loop. This would be the case if the cable shielding were connected at a second point in the control cabinet to

the cabinet itself or to the DIN rail. This would close the DIN rail – functional ground contact – printed-circuit board – shield connection clamp – shielding – DIN rail circuit, enabling interference voltages to be induced easily in this conductor loop, for example, during switching operations.

Housings with a quick locking system can also be opened easily during operation. The use of pull-out stops has proven to be effective in ensuring that the printed-circuit board cannot be inadvertently pulled completely out of the housing. The printed-circuit board can only be pulled completely out of the housing once the pull-out stop has been released.

Housings with a quick locking system are also frequently used if settings have to be made, for example, via potentiometer or DIP switch on the device printed-circuit board during commissioning or in the event of service actions. The PCB pull-out stop also prevents the printed-circuit board from being pulled completely out in this case.

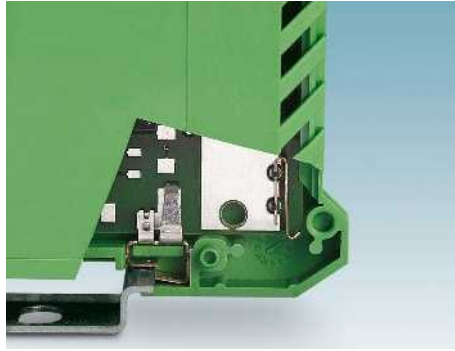


Fig. 49: FE contacts for ME housings



Fig. 50: FE contacts for UM profiles



Fig. 51: Shield connection clamp on an ME housing

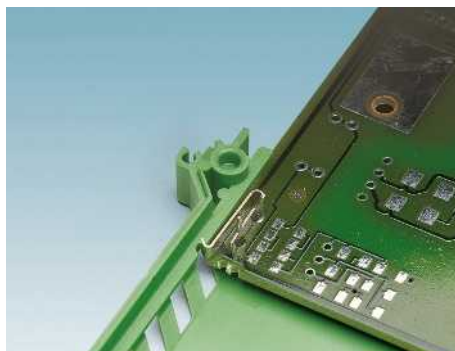


Fig. 52: PCB pull-out stop



# 6 Heat dissipation

An elementary challenge surrounding the operation of electronics housings is heat dissipation, because the electrical and consequently the mechanical components inside the housings heat up. In most cases, the critical temperatures for individual components are not exceeded. If, however, components do reach their performance limits, there must be sufficient heat transfer to reduce the temperature, otherwise the device may become damaged.

## 6.1 Heat transfer

A basic distinction is made between the three types of heat transfer involved in dissipating the heat from housings to the surroundings:

### 6.1.1 Heat radiation

Bodies emit heat to their surroundings via radiation. Because plastic, as the typical material for electronics housings, tends to insulate rather than conduct heat, this effect is hardly noticeable. Furthermore, devices for DIN rail mounting are often arranged very close to each other. This significantly restricts heat from being dissipated via the side walls. It is also possible that neighboring devices add additional heat. Better heat dissipation is achieved by positioning spacers between the devices. However, they increase the space requirements and must be taken into consideration early on during control cabinet planning.

### 6.1.2 Convection

If housings are equipped with ventilation slots on their narrow sides, a circulation of air develops if they are installed vertically: warm air rises and escapes via the upper ventilation slots. Colder air is drawn in through the lower ventilation slots, which is then heated by the hot components and, in turn, escapes through the upper slots. The resulting natural convection system only comes to a standstill once the surroundings and the device reach the same temperature level. Normally, this point is never reached, because the control cabinet surrounding the device absorbs heat itself and transfers this to the surroundings. In order to prevent the ingress of larger, solid foreign bodies, the maximum width of the ventilation slots in electronics housings is 2.5 mm, in accordance with the protection class IP 3x of DIN EN 60529.



### 6.1.3 Heat conduction

In this case, the heat transfer occurs within a substance via its molecular movements. With electronic devices, it is often the connected copper wires that dissipate a great deal of heat from the inside of the housing to the outside. This, of course, only happens if the live copper wires are colder than the device itself. Performing temperature tests on connected cables with the nominal cross section and under normal load and typical installation conditions is therefore recommended. This test setup should also include neighboring devices or cable ducts that impede heat transfer. Thermal imaging cameras provide an overview of the temperature conditions and heat sources – known as hot spots – in a housing.

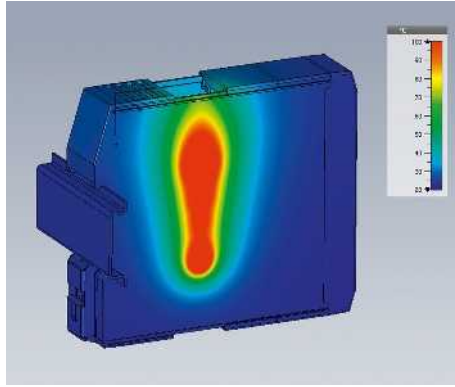


Fig. 53: Heat distribution without heatsink

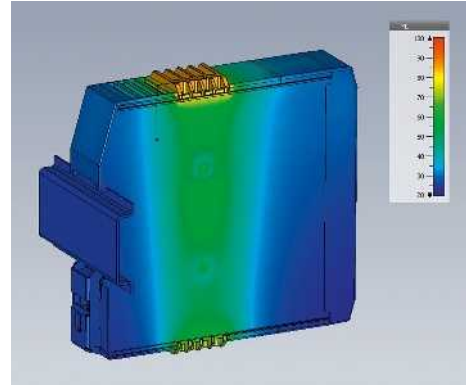


Fig. 55: Heat distribution with heatsink

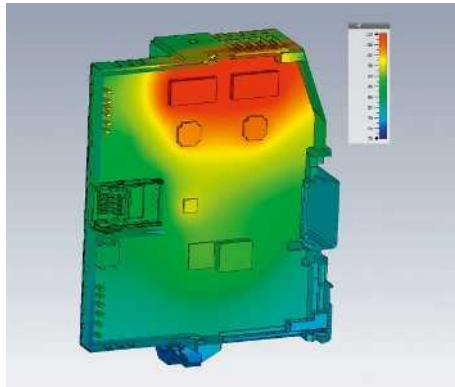


Fig. 54: Unfavorable component positioning

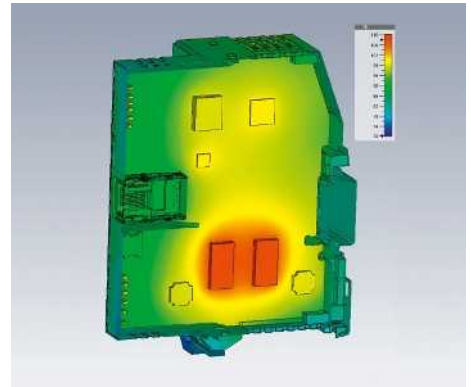


Fig. 56: More favorable component positioning

## 6.2 Thermal simulation of electronic devices

The technical data of electronics housings normally lists specifications on the temperature behavior. Usually this is the power dissipation, i.e., how much power a housing can dissipate in the selected design. Issues such as the size of the housing, the material, the mounting position, and the presence of ventilation slots play a role here. Thermal simulation has proven to be a useful method of checking whether the electronics to be introduced do not cause these limits to be exceeded. This method analyses the PCB layout to create a thermal map that captures both the active, heat-generating components and the passive heat-sensitive components.

Software then simulates the development of heat within the housing, the effect on neighboring components, the heat conduction, and heat radiation out of the housing into the surroundings. If ventilation slots are present and if the mounting position enables convection, this is also taken into consideration. With this information, it quickly becomes clear to what extent a housing is suitable for the desired application. Furthermore, the positioning of components can be optimized with this analysis. Does, for example, a particularly tall component impede convection and need to be moved?

The simulation itself is performed in

several steps. In the first step, a type of rough-calculation simulation determines whether a device will even approach the thermal limit range. If it will, a more precise analysis of the thermal behavior will be simulated in detail. Naturally, in borderline cases, verifying the result in a trial is to be recommended.



# 7 Plastic as a material for electronics housings

Plastics are technical materials that consist of macromolecules with organic groups and which are created by chemical reaction. They are manufactured fully synthetically through polymerization, the linkage of smaller molecules (monomers) to form macromolecules (polymers).

## 7.1 Technical plastics

Plastics get their strength from this macromolecular structure. They differ from each other due to:

- The type and arrangement of the atoms involved in their structure
- The form of the macromolecules
- The size of the macromolecules
- The arrangement of the macromolecules.

DIN 7728 specifies the abbreviations for the individual plastics.

Thermoplastics are often used for electromechanical elements. These plastics, which are tough and hard at normal temperatures, can be repeatedly heated to a plastically deformable state, although they will be degraded somewhat. Thermoplastics can be melted, welded, swollen, and dissolved. They are characterized by a low density, a relatively high chemical resistance to inorganic media, a high electrical insulating ability, and their versatile mechanical behavior. Disadvantages from an electromechanical engineering perspective are the limited temperature stability and the swelling behavior.

More than 90% of the electronics

housings on the market today are made of plastic due to the properties listed. The advantage lies in the easy formability, especially in mass production, in conjunction with the very good insulation properties and low weight.

However, not all thermoplastics have exactly the same properties. There are differences in the dimensional stability and the application in certain temperature ranges. The addition of fiberglass increases the hardness and rigidity in comparison with the base material.

### 7.1.1 Commonly used thermoplastics

- Polyamide PA retains its electrical, mechanical, and chemical properties, which are very well suited to electronics housings, even at high operating temperatures. Through heat stabilization, short-term peak temperatures of up to approximately 200°C are permitted. The absorption of water makes the plastic flexible and resistant to breakage.

- Polyamides (PA-GF) are polyamides reinforced with fiberglass for increasing rigidity and hardness.
- Polycarbonate (PC) combines many advantages such as rigidity, impact strength, transparency, dimensional stability, and resistance to heat. The amorphous material only absorbs moisture to a very limited degree, and is used for large, dimensionally stable electronics housings. In its transparent form it is used in covers or as a labeling material.
- Polyvinyl chloride (PVC) in powdered form is processed in extruders. It is used in profile production, whereas other thermoplastics are primarily processed as ready-to-use molding compounds in injection molding.
- Acrylonitrile butadiene styrene (ABS) is used for products that must have good impact and notched impact properties in addition to a high mechanical stability and rigidity. The products are also characterized by their special surface quality and hardness. ABS is suitable for coating metal surfaces, such as nickel.



In addition to the technical properties, which are listed in Table 6 in comparison with other better-known materials, the price of the plastics also plays a role. Particularly noteworthy here is the field of high-performance polymers with operating temperatures of more than 150°C. Such plastics are used for connection technology, which is used in the reflow process.

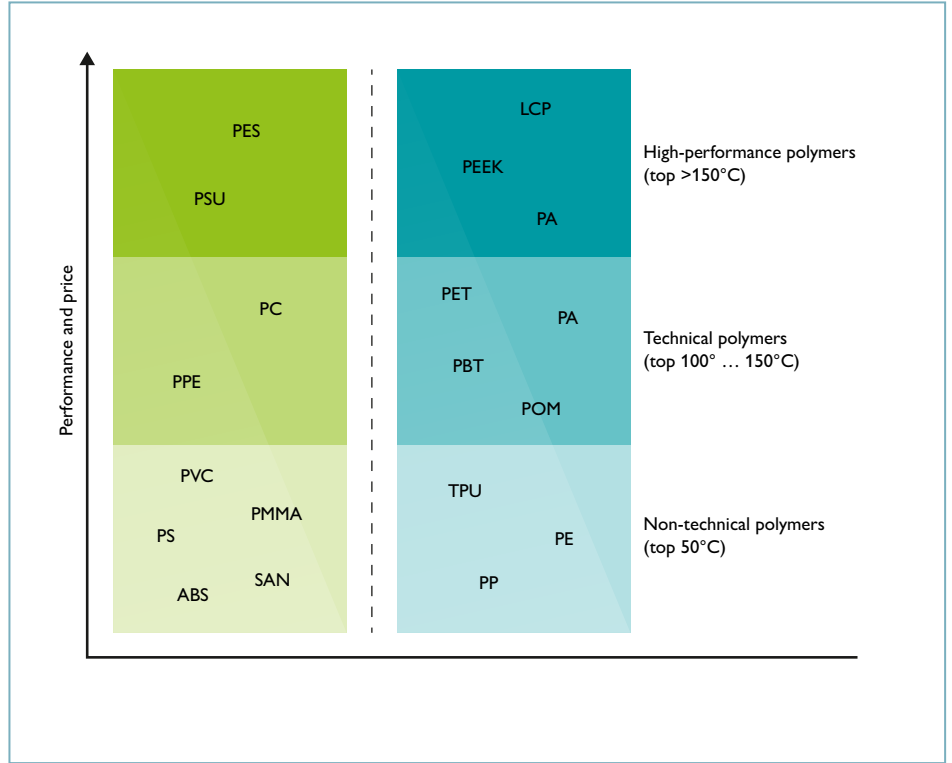


Fig. 57: Classification of various thermoplastics according to performance and price

Material	Heat quantity/ volume	Compressive strength (N/mm <sup>2</sup> )	Elongation under load (100 N/mm <sup>2</sup> )	Thermal conductivity (kJ)	Tensile strength (N/mm <sup>2</sup> )
Water	100%			2.1	
Iron	85%				400 ... 300
Thermoplastics	50 ... 33%	140 ... 80	80 ... 3.3	1.47 ... 0.37	70 ... 2
Thermosetting materials	48 ... 40%		3.1 ... 1.2		80 ... 40
Glass	40 ... 33%	2000 ... 800	0.15	2.94	100 ... 50
Wood	32 ... 21%	60 ... 20	1.5 ... 0.7		85 ... 60
Foamed material	0.3 ... 0.1%			0.21 ... 0.03	
Cast iron		600 ... 480			
Steel		420 ... 350	0.05	210	1000 ... 400
Stone			0.7 ... 0.1		
Copper				1344	

Table 6: Technical properties of various materials in comparison with thermoplastics

## 7.2 Material tests





Property	Standard	PA GF	PC	ABS	PVC
					
		ME/ME MAX polyamide A 6	BC polycarbonate PC	EH acrylonitrile butadiene styrene ABS	UM Basic polyvinyl chloride PVC, UM PRO polyamide PA
RTI <sup>1)</sup> elec.	UL 746B	>=105°C	>=105°C	>=80°C	>=50°C
Minimum operating temperature (without mechanical load)		-40°C	-40°C	-40°C	-15°C
Dielectric strength	IEC 60243-1	400 kV/cm	>300 kV/cm	850 kV/cm	
	DIN VDE 0303-1				
Resistance to creepage CTI <sup>2)</sup>	ICE 60112	400 V	175 V	600 V	600 V
	DIN VDE 0303-1				
Resistance to creepage CTI...M <sup>3)</sup>	IEC 60112	250 V	175 V	600 V	
	DIN VDE 0303-1				
Flammability rating	UL 94	V0/V2	V0/HB	V0/V2	V0

Table 7: Application-related technical data for plastics

The selection criteria for plastics in electrical applications are very diverse. For electronics housings, these are above all dimensional stability, temperature behavior, and compliance with fire-protection standards. A preliminary selection aided by appropriate material tests must be made in the development phase. This selection is based firstly on the operating temperature range and the fire behavior with different material thicknesses.

The temperature range is determined based on the intended application. A housing in a control cabinet is subjected to different conditions than one in the field. Another consideration is the heat generated by the device electronics. Which temperatures must the housing

withstand in the intended application? Finally, requirements listed in the corresponding device standards and approvals are also to be considered.

The dimensional stability of a plastic is a key consideration during the housing production process. Is it possible to produce the geometric shape with the wall thicknesses specified during development in an injection molding tool with dimensional stability, or will there be deformations or sagging? For example, polyamide can be used at higher temperatures even with thin wall thicknesses, but is not as dimensionally stable. Polycarbonate, on the other hand, is dimensionally much more stable, but cannot be used at the high temperatures that polyamide can. Then there is the

fire behavior, which does not only differ from material to material, but also very much depends on the material thickness. The material thickness, in turn, also has a great influence on the dimensional stability.

Appropriate material testing and the resulting specific values enable plastics to be reliably qualified for their suitability for use in electronics housings. Once the material selection has been made in terms of temperature and fire behavior, the Moldflow analysis, behavior during injection molding, and dimensional stability can be considered/investigated.

### 7.2.1 Relative thermal index (RTI)

The relative thermal index (RTI) in accordance with UL 746B is a characteristic parameter for the thermal resistance to aging of a plastic at an increased temperature. The RTI is defined as the temperature at which a material (candidate B), when stored in air, lasts for as long as a comparable other material (control A) at its already known RTI temperature, until the value of a specific property has dropped to 50% of its original value.

There is an RTI value for various material thicknesses, and typically for the following characteristics:

- Dielectric strength (RTI Elec.)
- Tensile strength (RTI Str.)
- Impact strength (RTI Imp.)

Insulation material group	$U_{prof}/V$	CTI failure criteria
I	$600 \leq CTI$	Residual current $I_r$ of $\geq 0.5 A$ for $\geq 2 s$ Flame forms in $\geq 2 s$
II	$400 \leq CTI < 600$	
III a	$175 \leq CTI < 400$	
III b	$100 \leq CTI < 175$	

Table 8: Insulation material groups in accordance with DIN EN 60664-1

### 7.2.2 Resistance to creepage (CTI, comparative tracking index)

The resistance to creepage characterizes the insulation resistance of the surfaces (creepage distance) of insulation materials, in particular under the influence of moisture and impurities. It defines the maximum creepage current which may be set under standardized test conditions (specified voltage, conductive layer material) in a defined test arrangement (electrode spacing, electrode shape).

A high resistance to creepage means that measurable currents on the surface of the test piece only occur when a correspondingly high voltage (CTI) is applied. The CTI value is only standardized for voltages of up to 600 V.

The relationship between the insulation material group and the CTI value is established in the EN 50124 standard.

The formation of the creepage path can be caused by contamination of the surface. The CTI test in accordance with the IEC/DIN EN 60112 standard attempts to simulate this by applying a conductive test solution.

The CTI value is needed for determining the creepage distances in accordance with DIN EN 60664. This standard contains the specifications for insulation coordination for equipment in low-voltage systems for use at altitudes up to 2000 m above sea level.

The voltages present, the properties of the insulation materials (CTI), and the expected pollution degree are considered when dimensioning creepage

distances. When determining the creepage distances, the effect of pollution is considered in accordance with three degrees of severity. The starting point for determining the creepage distances is, however, the rated voltage derived from the working voltage or nominal mains voltage. Further differentiations are then made between printed circuits and other applications. In addition to the creepage distances, the clearances occurring are also used for insulation coordination, but the CTI value does not come into play here.

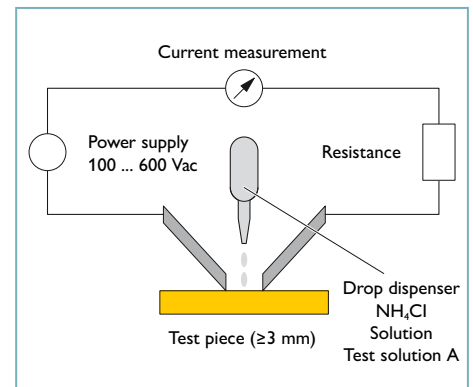


Fig. 58: Resistance to creepage test

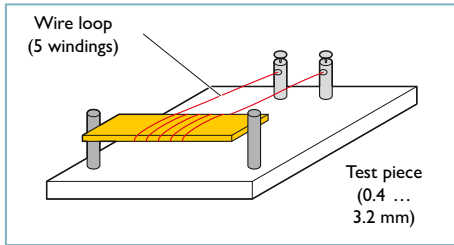


Fig. 59: Hot wire ignition test

### 7.2.3 Hot wire ignition test (HWI)

In the hot wire ignition test in accordance with ASTM D 3874, a horizontally arranged rod-shaped test piece is wrapped with an electrically heated resistance wire. This simulates an ignition source resulting from the overheating of wires, for example, a coil. The evaluation criterion for classification in the flammability categories PLC 0 to 5 in accordance with UL 746 A Section 31 is the time after which the sample ignites (0 to 120 seconds). PLC = performance level category.

### 7.2.4 High-current arc ignition test (HAI)

In the high-current arc ignition test in accordance with UL 746 A Section 32, a test piece between two electrodes is exposed to regularly recurring electric arcs. The HAI value rates the number of electric arcs up to ignition in the categories PLC 0 to 4.

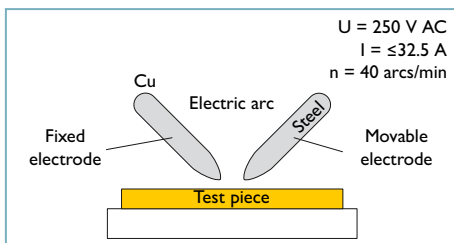


Fig. 60: High-current arc ignition test

## 7.2.5 Flammability classification in accordance with UL 94

The UL 94 regulation is of particular importance. Its content has been incorporated word for word into the DIN IEC 60695-11-10 and -20 standards as well as the Canadian CSA C 22.2 standard. Test flames with a power of 50 or 500 watts are used as the ignition source, and are applied briefly to the test piece twice. The burning time is evaluated as well as the dripping of burning parts, which is evaluated with the help of cotton wadding arranged under the test piece. The tested test piece thickness is classified in the levels 5V, V-0, V-1, V-2 (vertical test), and HB (horizontal test). In the case of colored base materials, approval must be provided in combination with the color batch.

This is documented along with the other tests listed on a UL Yellow Card under a material-specific E number.

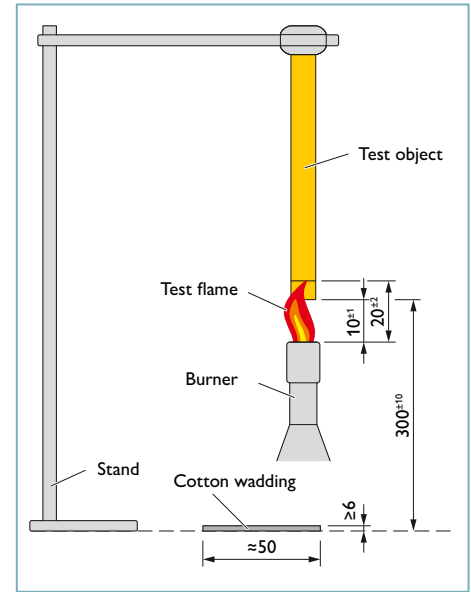


Fig. 61: Vertical test in accordance with DIN IEC 60695

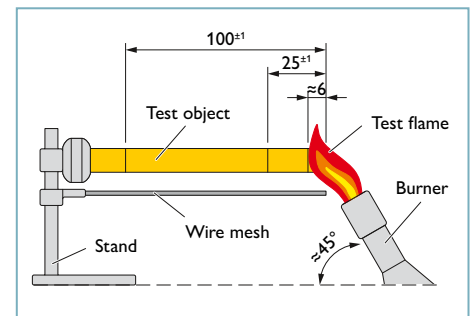


Fig. 62: Horizontal test in accordance with DIN IEC 60695

#### Horizontal test setup UL 94 HB flame 50 W

Test thickness	Burning rate	Class	
Any, flame extinguishes before 100 mm	-	HB	
3 ... 13 mm	$\leq 40$ mm/min	HB	
<3 mm	$\leq 75$ mm/min	HB	

#### Vertical test setup UL 94 flame 50 W

Test thickness	V 0	V 1	V 2
Burning time after each flame application	$\leq 10$ s	$\leq 30$ s	$\leq 30$ s
Total burning time per set (10 flame applications)	$\leq 50$ s	$\leq 250$ s	$\leq 250$ s
Burning and afterglow times after second flame application	$\leq 30$ s	$\leq 60$ s	$\leq 60$ s
Combustion up to holding clamp	No	No	No
Ignition of cotton wadding	No	No	Yes

Table 9: Test criteria in accordance with UL 94/DIN IEC 60695-11-10

## 7.3 Material certification

Plastics have to be subjected to the above listed tests before they can be used in electrical applications. The plastics themselves are tested, not the housing made from them. Therefore, test pieces are used in the tests and not individual products. The regulations of UL 94 (Underwriters Laboratories) are mainly used. These have been incorporated into the DIN IEC 60695-11-10 and -20 standards as well as the Canadian CSA C 22.2 standard. The results of such a material test are recorded specifically to the material and manufacturer on a Yellow Card. These can be used to look up the behavior of a plastic with a listed material thickness. Information on which colors these values apply to is also to be found here. A Yellow Card can therefore refer to all colors of a material or only to the colors listed there. This does not necessarily mean that other colors did not pass this test. It may be that for cost reasons, only a few of the available colors were tested. Table 10 is an example of a typical representation of the characteristic values on such a Yellow Card.

Color	Minimum material thickness (mm)	Flammability rating	HWI	HAI	RTI Elec.	RTI Imp.	RTI Str.
All	0.25	V 0	4	1	65	65	65
	0.38	V 0	4	1	130	105	115
	0.75	V 0	4	0	130	105	120
	1.5	V 0	4	0	130	105	120
	3.0	V 0	3	0	130	105	120

Table 10: Typical representation of the material characteristic values for UL-certified plastics



## 8 Tests on electronics housings

Once the development of an electronics housing has been completed and the first pre-series products have been made, the selected properties must be tested in the laboratory. There are a number of standards to be used as the basis for these tests. In addition to the material tests and those for the mechanical properties, which were worked toward during development, tests are still necessary for testing the behavior of the product under operating conditions.

### 8.1 Thermal and mechanical tests

#### 8.1.1 Test for assessing the risk of fire

In the glow-wire test in accordance with DIN EN 60695-2.10:2014-04 or VDE 0471-2-10:2014-04, the behavior of an electronics housing is examined under the direct influence of an external ignition source. The housing must extinguish itself within a specified period of time. Furthermore, there must not be a danger from falling, burning drops.

Housings made of polyamide are tested at a temperature of 850°C with an exposure time of 30 s. The time taken to ignite the test object and to extinguish the flame after removing the ignition source as well as the number of falling drops are recorded. The test is considered passed if the underlay (tissue paper) does not ignite within the 30 seconds.

#### 8.1.2 Mechanical strength (tumbling barrel test)

The stability of the fully assembled housing is tested in the tumbling barrel test in accordance with DIN EN 60998-1 or VDE 0613-1:2005-03. The focus here is on latching systems, locking systems, and screw connections. The housing falls 50 times from a height of 50 cm in the rotating barrel. The rotation speed is 5 rpm, which equates to 10 drops per minute.

If the latching systems and locking systems have not loosened after 50 falls, and no housing parts have chipped or broken off, the test is considered passed.



Fig. 63: Glow-wire test



Fig. 64: Tumbling barrel test



Fig. 65: Test for mechanical seal tightness

### 8.1.3 Test for mechanical seal tightness

In order to be able to make a statement on the mechanical tightness of the seal against the ingress of solid bodies and liquids, the housings are tested based on the product standard for connectors – DIN EN 61984 (VDE 0627):2002-9 – and the results are evaluated in accordance with DIN EN 60529.

Since housings for mounting on a DIN rail are usually located in a control cabinet or a machine, the test for these housings is limited. These housings are not expected to be exposed to a dusty or humid environment.

For field housings that are used outside the control cabinet, this test applies in full. The housings are sprayed, exposed to jet water or even completely submerged.

First digit		Description	
ISO 20653	DIN EN 60529	Protection against foreign bodies	Protection against contact
0	0	No protection	No protection
1	1	Protection against solid bodies with a diameter $\geq 50$ mm	Protection against touching with back of hand
2	2	Protection against solid bodies with a diameter $\geq 12.5$ mm	Protection against touching with fingers
3	3	Protection against solid bodies with a diameter $\geq 2.5$ mm	Protection against touching with a tool
4	4	Protection against solid bodies with a diameter $\geq 1.0$ mm	Protection against touching with a wire
5K	5	Protection against dust	Complete protection against contact
6K	6	Dust-tight	Complete protection against contact

Table 11: First digit of the IP code

Second digit		Description
ISO 20653	DIN EN 60529	
0	0	No protection
1	1	Protection against dripping water
2	2	Protection against dripping water at a housing tilt angle of $15^\circ$
3	3	Protection against spray water up to $60^\circ$ to the vertical
4	4	Protection against splash water from all directions
4K		Protection against splash water with increased pressure from all directions
5	5	Protection against jet water from any angle
6	6	Protection against powerful jet water
6K		Protection against powerful jet water with increased pressure, specific to road vehicles
7	7	Protection against temporary submersion
8	8	Protection against long-term submersion
	9	Protection against water during high-pressure/jet-stream cleaning, especially in agriculture
9K		Protection against water during high-pressure/jet-stream cleaning, specific to road vehicles

Table 12: Second digit of the IP code



Fig. 66: Dust test

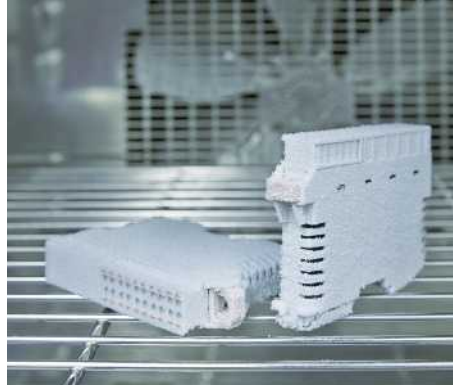


Fig. 67: Durability test



Fig. 68: Torque test

### 8.1.4 Dust test in accordance with DIN EN 60529

The dust protection test is one of the tests for determining the first digit of the IP degree of protection code in accordance with DIN EN 60529. For this test, an underpressure is generated within the housing to be tested. It is then placed in a closed chamber containing talcum powder. The temperature inside the chamber is to be between 15°C and 35°C at a relative humidity of 25% to 75% and an air pressure of 860 ... 1060 mbar. The underpressure in the housing is 20 mbar. The powder density is 2 kg/m<sup>3</sup>. If there is insufficient sealing, the talcum powder will be drawn into the housing due to the underpressure. The test is considered passed if, after an exposure time of 8 hours, there is not a visible layer of powder in the housing interior. This test is only used for housings intended for field use, i.e., not inside the control cabinet.

### 8.1.5 Durability test in accordance with DIN EN 0620-1-2010.02

Long-term exposure to heat/cold will always lead to the plastic aging, which results in a change in the mechanical and electrical properties. In order to simulate the complete life cycle of an electronics housing, it is exposed to extreme temperature and humidity conditions in the laboratory. Cold, damp or dry heat must not impair the functionality. As the test objects undergo the tests, the life cycle is simulated in terms of the temperature behavior rapidly.

According to DIN EN 0620-1-2010.02, a temperature of 70°C +/- 2°C is required for 168 h, followed by storage for at least 96 h at a relative humidity of 45 ... 55%.

The test is passed if the test objects do not exhibit any external damage and functionality is retained.

### 8.1.6 Connection technology tests in accordance with IEC 60947-7 and IEC 60999

The connection technology belonging to a housing system, as with all other terminal connections, is also tested in accordance with the relevant standards. In the torque test (IEC 60947), screws are tightened and loosened several times with the torque specified for them. The terminal point must complete this test without any recognizable damage.

Furthermore, conductor pull-out tests in accordance with IEC 60947-7-1/2 and IEC 60999 are performed at terminal points. In this test, the terminal point must withstand the tensile force assigned to the respective connection cross section for 60 s (Table 13). As an intensification of this test, a flexion test can be performed beforehand, in which the conductor is laden with a weight and turned through its own axis 135 times via a rotating disk. At the end of this test, the conductor and terminal point must not exhibit any damage.

<b>Cross section mm<sup>2</sup></b>	0.2		0.5	0.75	1.0	1.5	2.5	4	6	10	16	25	35
<b>Tensile force N</b>	10		20	30	35	40	50	60	80	90	100	135	190

Table 13: Relationship between tensile force and cross section

## 8.2 Vibration and shock in accordance with DIN EN 60068-2-6 and 60068-2-27

### 8.2.1 Vibration

For a practical simulation of the vibration stress, the electronics housings are subjected to broadband noise-induced vibrations in all three spatial directions. The vibration test described in the IEC 60068-2-6 standard is used for this. Harmonic, sinusoidal vibrations are applied to the test object to simulate rotating, pulsating or oscillating forces. The test is performed in each of the three spatial axes (X, Y, Z). The test is performed over a frequency range of 10 ... 150 Hz. The acceleration is 5g at an amplitude of 0.35 mm. The test is considered passed if there is no visible damage on the housing and no connections or latching systems have become loose inside the housing.

### 8.2.2 Shock

This test is performed to test and document the resistance of an electronics housing to shocks of varying energies occurring at irregular intervals. The acceleration and duration are specified as a definition of the shock. IEC 60068-2-27 prescribes three positive and negative shocks in each of the three spatial axes (X, Y, Z). The simulated accelerations reach 50 m/s<sup>2</sup> with a shock duration of 30 ms. The housings must not exhibit any damage upon completion of the test. Special attention is to be focused on the area of the base latch. In addition, no individual parts or housing latching systems must have become loose.

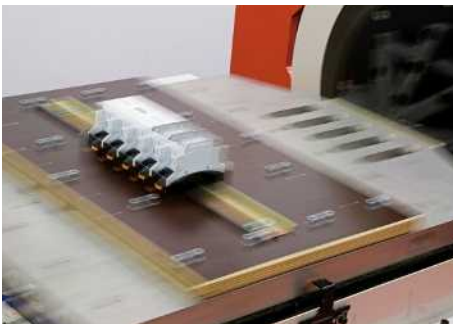


Fig. 69: Vibration test

<b>Frequency</b>	10 – 150 – 10 Hz
<b>Speed</b>	1 octave/min
<b>Amplitude</b>	0.35 mm
<b>Acceleration</b>	5g
<b>Test duration</b>	2.5 h per axis
<b>Test direction</b>	X, Y, and Z axis

Table 14: Vibration test conditions

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